Request by Lamont-Doherty Earth Observatory for an Incidental Harassment Authorization to Allow the Incidental Take of Marine Mammals During a Marine Seismic Survey on the Blanco Fracture Zone in the Northeastern Pacific Ocean, July 2004

submitted by

Lamont-Doherty Earth Observatory
61 Route 9W, P.O. Box 1000
Palisades, NY 10964-8000

to

National Marine Fisheries Service
Office of Protected Resources
1315 East–West Hwy, Silver Spring, MD 20910-3282

Application Prepared by

LGL Ltd., environmental research associates
22 Fisher St., POB 280, King City, Ont. L7B 1A6

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SUMMARY

Lamont-Doherty Earth Observatory (L-DEO), a part of Columbia University, operates the oceanographic research vessel R/V *Maurice Ewing* (*Ewing*) under a cooperative agreement with the U.S. National Science Foundation (NSF), owner of that vessel. L-DEO plans to conduct a marine seismic survey in the Northeastern Pacific Ocean (NPO), off Oregon, during July 2004. L-DEO requests that it be issued an Incidental Harassment Authorization (IHA) allowing non-lethal takes of marine mammals incidental to the planned seismic survey in the NPO. This request is submitted pursuant to Section 101 (a) (5) (D) of the Marine Mammal Protection Act (MMPA), 16 U.S.C. § 1371 (a) (5).

Up to two seismic surveys are scheduled to take place in the NPO from 8–23 July 2004 (Fig. 1). The main survey is planned to occur near the intersection of the Blanco Transform with the Juan de Fuca Ridge. A second survey may be conducted, time permitting; that contingency survey would be located at Gorda Ridge. The main seismic survey will take place offshore outside of territorial waters or the Exclusive Economic Zone (EEZ) of any nation, however the contingency survey is located within the EEZ of the U.S.A.

Numerous species of cetaceans and pinnipeds occur in the study area in the NPO. Several of the species are listed as "Endangered" under the U.S. Endangered Species Act (ESA), including sperm, humpback, sei, fin, blue, and North Pacific right whales. The "Threatened" Steller sea lion may also occur in the study area. L-DEO is proposing a marine mammal monitoring and mitigation program to minimize the impacts of the proposed activity on marine mammals present during conduct of the proposed research, and to document the nature and extent of any effects. Special mitigation measures will be implemented for the North Pacific right whale, because of the rarity and sensitive status of this species.

The items required to be addressed pursuant to 50 C.F.R. § 216.104, "Submission of Requests" are set forth below. This includes descriptions of the specific operations to be conducted, the marine mammals occurring in the study area, proposed measures to mitigate against any potential injurious effects on marine mammals, and a plan to monitor any behavioral effects of the operations on those marine mammals. No measures will be necessary to minimize conflicts between the proposed operation and subsistence hunting, because no hunting of marine mammals occurs in or near the area of the proposed activity.

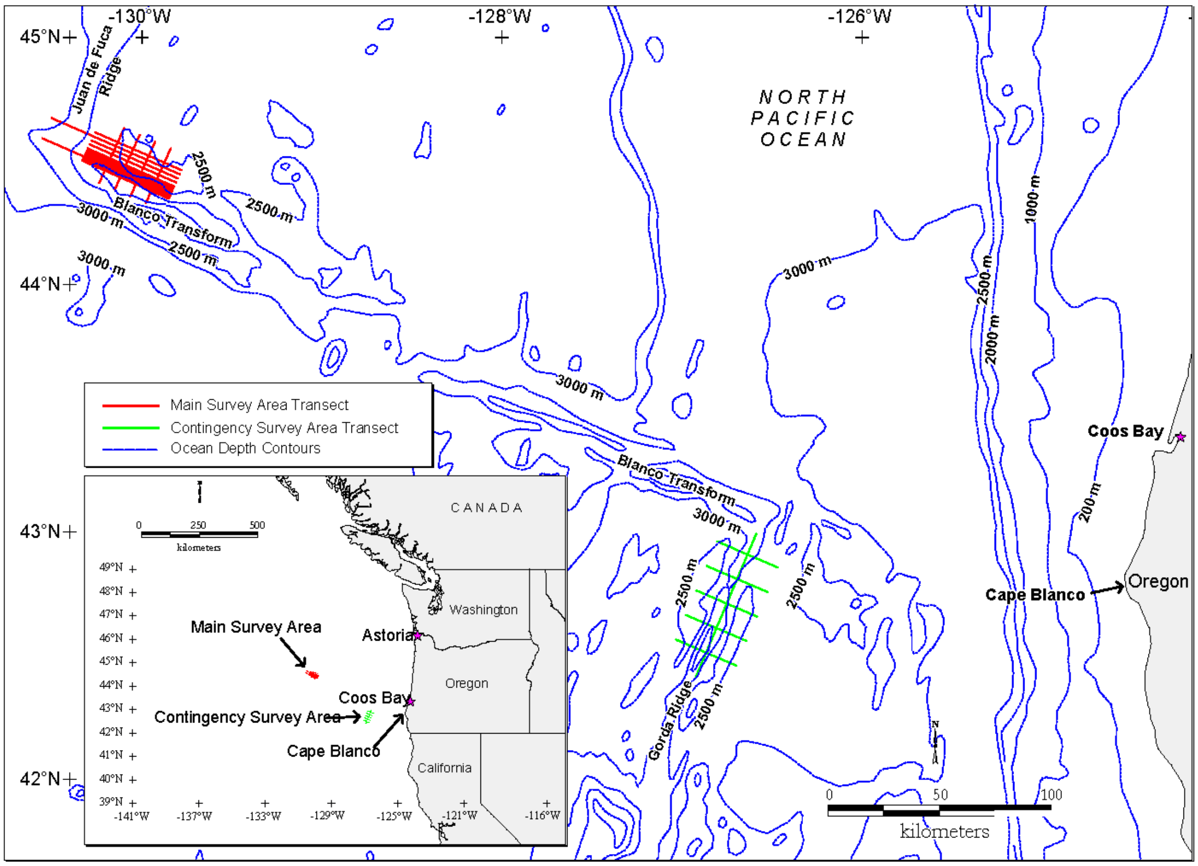

FIGURE 1. Location of study area in the Northeastern Pacific Ocean, showing both the main survey area (Blanco Transform) and the contingency survey area (Gorda Ridge).

I. OPERATIONS TO BE CONDUCTED

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

Overview of the Activity

Lamont-Doherty Earth Observatory (L-DEO), on behalf of the National Science Foundation, plans to conduct a seismic survey at least 157 km (84 n.mi.) off Oregon in the Northeastern Pacific Ocean (NPO) in July 2004, with the primary survey to occur about 450 km (243 n.mi.) off the coast of Oregon.

The purpose of the seismic survey is to obtain information on the structure of the oceanic crust created at the Juan de Fuca Ridge. More specifically, the survey will obtain information on the geologic nature of boundaries of the earth's crust created at the intermediate-spreading Juan de Fuca Ridge. Past studies have mapped those boundaries using manned submersibles, but they have not provided a link between geologic and seismic structure. This study will provide the seismic data to assess the geologic nature of the previously mapped areas.

The proposed seismic survey will involve one vessel, the R/V *Maurice Ewing*. The *Ewing* will deploy a 10- or 12-airgun array as an energy source, with discharge volumes of 3050 in^3 and 3705 in^3, respectively. The *Ewing* will also deploy and retrieve 12 Ocean Bottom Seismometers (OBSs), plus a 6-km towed streamer containing hydrophones, to receive the returning acoustic signals. As the airguns are towed along the survey lines, these two receiving systems will receive the returning acoustic signals.

Up to two seismic surveys are scheduled to take place in the NPO (Fig. 1). The main survey is planned to occur near the intersection of the Blanco Transform with the Juan de Fuca Ridge (Fig. 2). The area within which the main seismic survey will occur is located between 44º20' and 44º42'N and between 129º50' and 130º30'W. A second survey may be conducted, time permitting; that contingency survey would be located at Gorda Ridge between 42º20' and 43ºN and between 126º30' and 127ºW (Fig. 3).

A total of ~150 km (81 n.mi.) of OBS surveys using a 12-gun array and ~1017 km (549 n.mi.) of Multi-Channel Seismic (MCS) profiles using a 10-gun array are planned to be conducted during the main survey (Fig. 2). Those line-kilometer figures include operations associated with start up, line changes (10 km or 5 n.mi. for the 12-gun array and 90 km or 49 n.mi. for the 10-gun array), equipment testing, contingency profiles, and repeat coverage of any areas where initial data quality is sub-standard. In the unlikely event that there are no weather or equipment delays, additional MCS profiles may be acquired at the northern end of the Gorda Ridge where it intersects the Blanco Transform (Fig. 3). The contingency survey would consist of 220 km (119 n.mi.) of survey lines, plus 63 km (34 n.mi.) for turns and connecting lines, for a total of 283 km (153 n.mi.). Water depths within the seismic survey area are 1600–5000 m (5250–16,405 ft).

All planned geophysical data acquisition activities will be conducted by L-DEO with on-board assistance by the scientist who has proposed the study. The principal investigator is Dr. Gail Christeson of the University of Texas at Austin, TX. The vessel will be self-contained, and the crew will live aboard the vessel for the entire cruise.

Procedures to be used for the proposed seismic survey and associated marine mammal monitoring will be similar to those during previous seismic surveys by L-DEO, e.g., in the equatorial Pacific Ocean (Carbotte et al. 1998, 2000). The proposed program will use conventional seismic methodology with a towed airgun array as the energy source, and a towed hydrophone streamer and/or ocean bottom seismometers (OBSs) as the receiver system. The energy to the airgun array will be compressed air supplied by compressors on board the source vessel.

In addition to the airgun array, a multibeam bathymetric sonar (15.5 kHz hydrosweep) will be operated from the source vessel continuously throughout the entire cruise, and a lower-energy 3.5 kHz sub-bottom profiler will also be operated during most of the survey.

Vessel Specifications

The *Ewing* will be used as the source vessel for the airgun sounds. It will tow the airgun array (either 10 or 12 guns) and a streamer containing hydrophones along predetermined lines. It will also deploy and retrieve the OBSs. The *Ewing* has a length of 70 m (230 ft), a beam of 14.1 m (46.3 ft), and a draft of 4.4 m (14.4 ft). The *Ewing* has four 1000 kW diesel generators that supply power to the ship. The ship is powered by four 800 hp electric motors that, in combination, drive a single 5-blade propeller in a Kort nozzle and a single-tunnel electric bow thruster rated at 500 hp. At the typical operation speed of 7.4–9.3 km/h (4–5 knots) during seismic acquisition, the shaft rotation speed is about 90 rpm. When

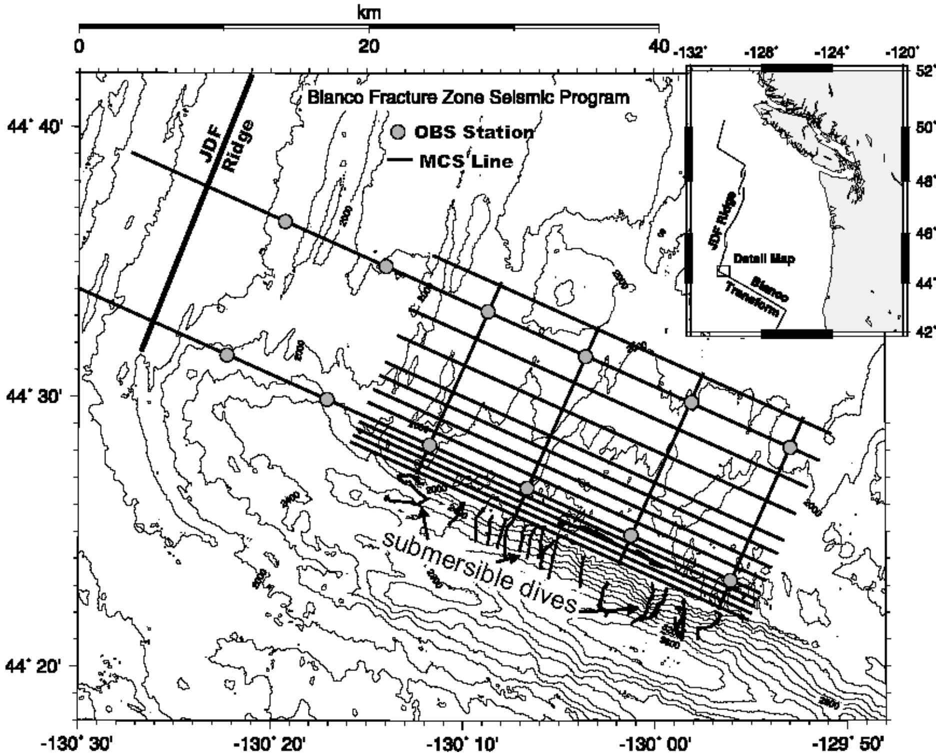

FIGURE 2. Location of the main study area in the Northeastern Pacific Ocean, ~450 km (243 n.mi.) off the Oregon coast, near the intersection of the Blanco Transform with the Juan de Fuca Ridge, including proposed tracklines and OBS locations. OBS profiles will be acquired along the two long lines along which OBSs will be deployed (shown by circles). The MCS survey lines are spaced as follows: the five northern-most lines are 2 km (1.1 n.mi.) apart, the next five lines are 1 km (0.5 n.mi.) apart, and the southern-most survey lines are 0.5 km (0.3 n.mi.) apart. The four NNE–SSW lines are situated 7.5 km (4.0 n.mi.) apart. No submersible dives will occur during the planned project in July 2004.

not towing seismic survey gear, the *Ewing* cruises at 18.5–20.4 km/h (10–11 knots) and has a maximum speed of 25 km/h (13.5 knots). It has a normal operating range of about 31,500 km (17,000 n.mi.).

The *Ewing* will also serve as the platform from which vessel-based marine mammal observers will watch for mammals before and during airgun operations. The characteristics of the *Ewing* that make it suitable for visual monitoring are described in § XI, MITIGATION MEASURES.

Other details of the *Ewing* include the following:

Owner:	National Science Foundation
Operator:	Lamont-Doherty Earth Observatory of Columbia University
Flag:	United States of America
Date Built:	1983 (modified in 1990)
Gross Tonnage:	1978
Fathometers:	3.5 and 12 kHz hull mounted transducers; Furuno FGG80 Echosounder; Furuno FCU66 Echosounder Recorder
Bottom Mapping Equipment:	Atlas Hydrosweep DS-2, 15.5 kHz (details below)
Compressors for Air Guns:	LMF DC, capable of 1000 scfm at 2000 psi (scfm = standard cubic feet per minute)
Accommodation Capacity:	21 crew plus 3 technicians and 26 scientists

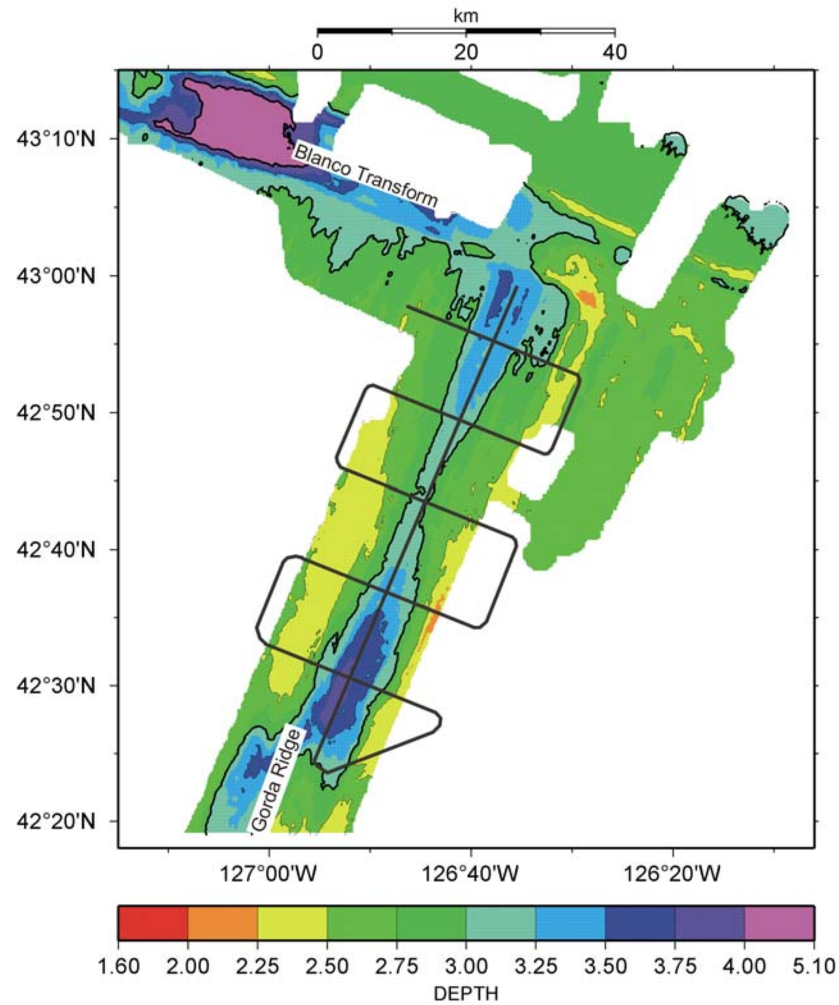

FIGURE 3. Location of extra contingency survey lines at the northern end of the Gorda Ridge where it intersects the Blanco Transform, ~157 km (84 n.mi.) from the Oregon coast. The MCS survey lines are spaced 12 km (6.5 km) apart. This contingency survey will only occur if time permits.

Airgun Array Descriptions

The airgun arrays to be used from the *Ewing* during the proposed program will consist of 10 or 12 airguns. The 10-airgun array (Fig. 4) will be used during MCS profiles and the 12-airgun array (Fig. 5) will be used during OBS surveys. The airguns will be widely spaced in an approximate rectangle of dimensions 35 m (across track) by 9 m (along track). Individual airguns range in size from 80 to 850 in^3, and the discharge volumes of the 10- and 12-airgun arrays total 3050 and 3705 in^3, respectively. Although the discharge volumes of the 10- and 12-airgun arrays to be used during the proposed survey differ from L-DEO's standard 10- and 12-airgun arrays (3005 and 3721 in^3, respectively), the arrays will not differ significantly in source output, as the number of airguns has a greater effect on source output than discharge volume.

10-Airgun Array Specifications

Energy Source	Ten 2000-psi Bolt airguns of 80–850 in^3
Approx. Source output (downward)	0-pk is 25 bar-m (248 dB re 1 μPa·m); pk-pk is 55 bar-m (255 dB)
Towing depth of energy source	7.0 m
Air discharge volume	3050 in^3
Dominant frequency components	0–188 Hz
Gun positions used	see Fig. 4
Gun volumes at each position (in^3)	see Fig. 4

12-Airgun Array Specifications

Energy Source	Twelve 2000-psi Bolt airguns of 80–850 in^3
Approx. Source output (downward)	0-pk is 31 bar-m (250 dB re 1 μPa·m); pk-pk is 68.2 bar-m (257 dB)
Towing depth of energy source	7.0 m
Air discharge volume	3705 in^3
Dominant frequency components	0–188 Hz
Gun positions used	see Fig. 5
Gun volumes at each position (in^3)	see Fig. 5

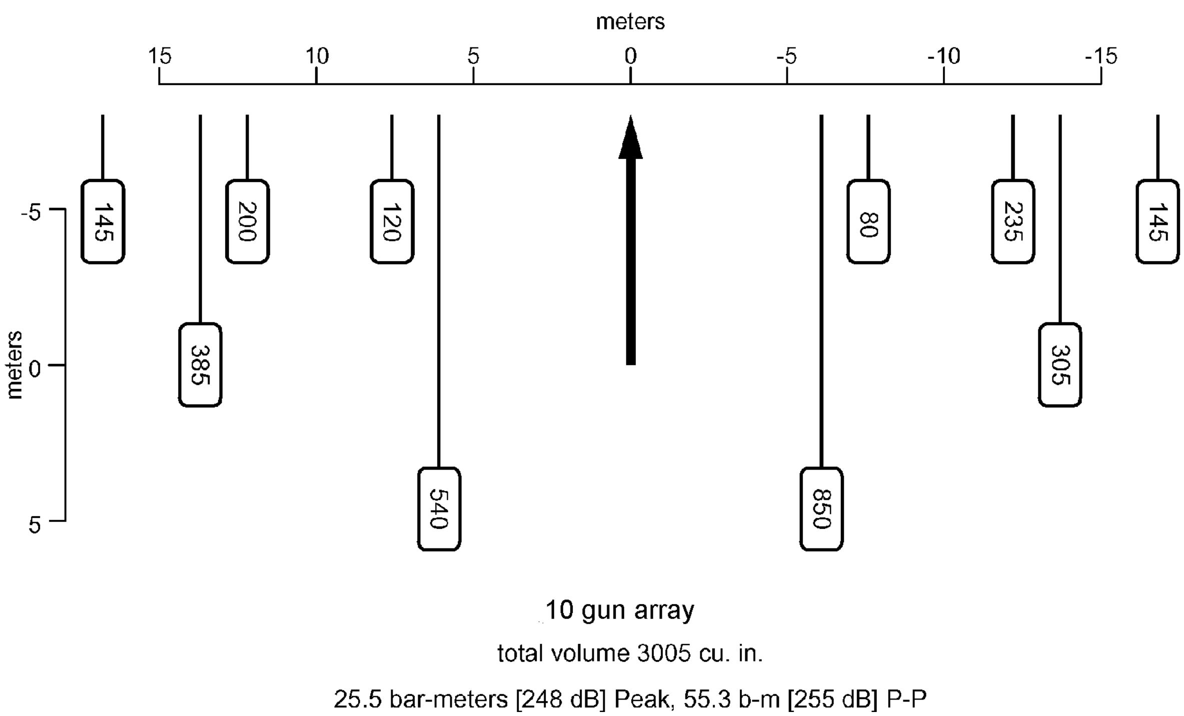

FIGURE 4. Configuration of L-DEO's standard 10-airgun array; the array to be used during the seismic survey in the Northeastern Pacific Ocean off Oregon during July 2004 will vary slightly from this array (see text).

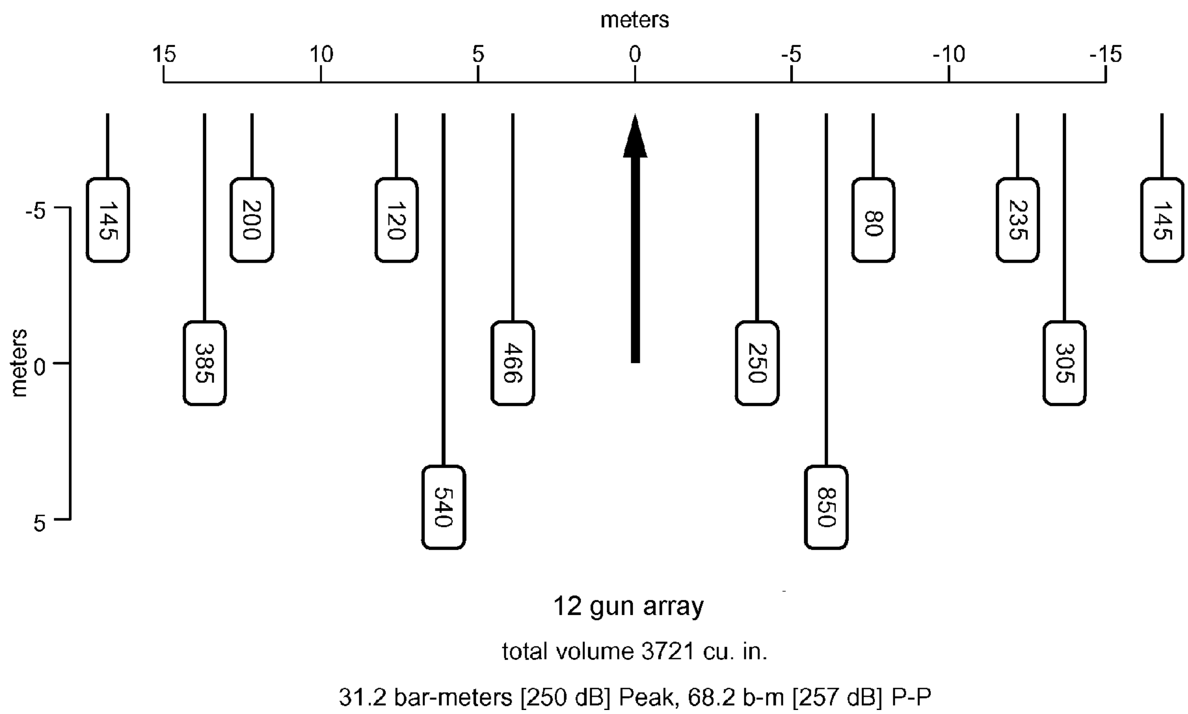

FIGURE 5. Configuration of L-DEO's standard 12-airgun array; the array to be used during the seismic survey in the Northeastern Pacific Ocean off Oregon during July 2004 will vary slightly from this array (see text).

For the 10- and 12-airgun arrays, the sound pressure fields have been modeled by L-DEO in relation to distance and direction from the airguns, and in relation to depth. Predicted received sound levels are depicted in Figures 6 and 7. Table 1 shows the maximum distances from those airgun arrays where sound levels of 190, 180, 170 and 160 dB re 1 µPa (rms[1]) are predicted to be received.

Empirical data concerning those sound levels have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (see separate IHA application, EA, and 90-day report). L-DEO's analysis of the acoustic data from that study (Tolstoy et al. 2004) provides limited measurements in deep water, the situation relevant here. Those data indicate that, for deep water, the model tends to overestimate the received sound levels at a given distance. Until additional data become available, it is proposed that the 190 and 180 dB (rms) distances (="safety radii") will be the values predicted by L-DEO's model during airgun operations in deep water, including the planned operations off Oregon.

When operations with the 10- or 12-airgun array commence after a period without airgun operations, the number of guns firing will be increased gradually or "ramped up". This process is described as a "soft start" in some jurisdictions; see § XI, "MITIGATION MEASURES". Operations will begin with the smallest gun in the array (80 in^3). Guns will be added in a sequence such that the source

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[1] The rms (root mean square) pressure is an average over the pulse duration. It is the measure commonly used in studies of marine mammal reactions to airgun sounds, and in NMFS guidelines concerning levels above which "taking" might occur. The rms level of an airgun pulse is typically about 10 dB less than its peak level (Greene 1997; McCauley et al. 1998, 2000a).

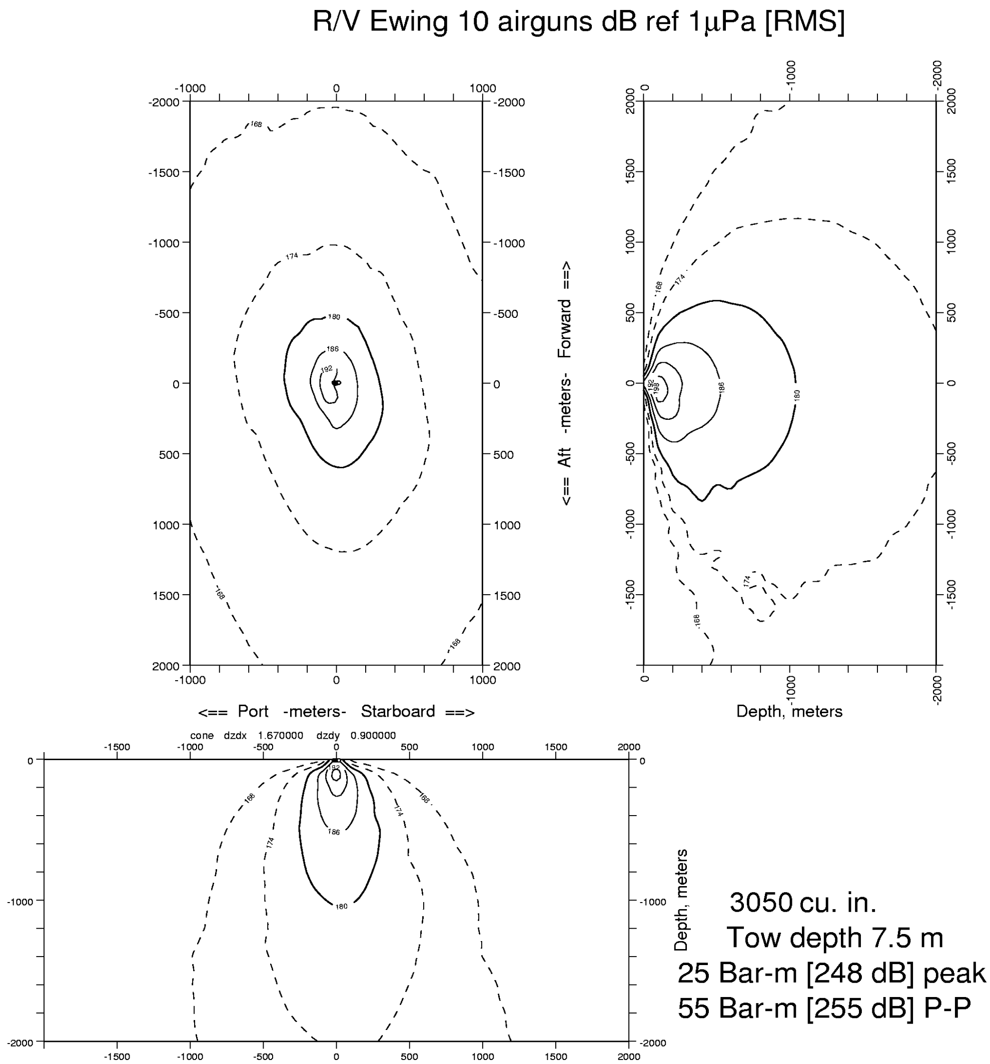

FIGURE 6. Modeled received sound levels from the standard 10-airgun array, which is similar to the array that will be used during the seismic survey in the Northeastern Pacific Ocean off the coast of Oregon in July 2004.

level of the array will increase in steps not exceeding 6 dB per 5-minute period over a total duration of ~18–20 min.

Multibeam Sonar and Sub-bottom Profiler

Along with the airgun operations, two additional acoustical data acquisition systems will be operated during much or all of the cruise. The ocean floor will be mapped with an Atlas Hydrosweep DS-2 multibeam 15.5-kHz bathymetric sonar, and a 3.5-kHz sub-bottom profiler will also be operated along with the multibeam sonar. These sound sources are commonly operated from the *Ewing* simultaneous with the airgun array. Their characteristics are described below.

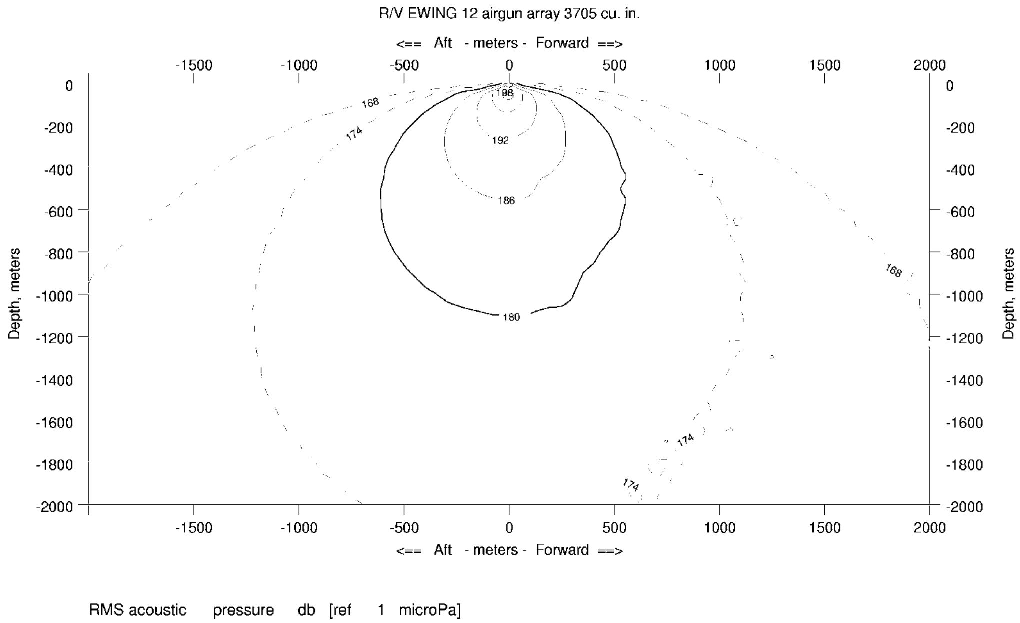

FIGURE 7. Modeled received sound levels from the standard 12-airgun array, which is similar to the array that will be used during the seismic survey in the Northeastern Pacific Ocean off the coast of Oregon in July 2004.

TABLE 1. Distances to which sound levels ≥190, 180, 170 and 160 dB re 1 μPa (rms) might be received from the 10- and 12-airgun arrays that are planned for use during the seismic survey in the Northeastern Pacific Ocean, off Oregon in July 2004. The distances are assumed to be the same as for the standard 10- and 12-gun arrays. Predicted radii for a single 80 in^3 airgun are also shown.

Airgun Array Volume	Airgun Depth (m)	Predicted RMS Radii (m)			
		190 dB	180 dB	170 dB	160 dB
80 in^3 (1 airgun)	7.0	13	36	110	350
3050 in^3 (10 airguns)	7.0	200	550	2000	6500
3705 in^3 (12 airguns)	7.0	200	600	2200	7250

Atlas Hydrosweep

This 15.5-kHz sonar is mounted in the hull of the *Ewing*, and it operates in three modes, depending on the water depth. There is one shallow water mode and there are two deep-water modes: an Omni mode and a Rotational Directional Transmission mode (RDT mode). ***(1)*** When water depth is <400 m, the source output is 210 dB re 1 μPa·m rms and a single 1-millisecond pulse or "ping" per second is transmitted, with a beam width of 2.67 degrees fore-aft and 90 degrees athwartship. The beam width is measured to the –3 dB point, as is usually quoted for sonars. ***(2)*** The Omni mode is identical to the shallow-water mode except that the source output is 220 dB rms. The Omni mode is normally used only during start up. ***(3)*** The RDT mode is normally used during deep-water operation and has a 237 dB rms source output. In the RDT mode, each "ping" consists of five successive transmissions, each ensonifying a beam that extends 2.67 degrees fore-aft and ~30 degrees in the cross-track direction. The five successive transmissions (segments) sweep from port to starboard with minor overlap, spanning an overall cross-track angular extent of about 140 degrees, with tiny (<<1 millisec) gaps between the pulses for successive 30-degree segments. The total duration of the "ping", including all five successive segments, varies with water depth, but is 1 millisec in water depths <500 m and 10 millisec in the deepest water. For each segment, ping duration is $1/5^{th}$ of these values or $2/5^{th}$ for a receiver in the overlap area ensonified by two beam segments. The "ping" interval during RDT operations depends on water depth and varies from once per second in <500 m (1640.5 ft) water depth to once per 15 seconds in the deepest water.

Sub-bottom Profiler

This device is normally operated to provide information about the sedimentary features and the bottom topography that is simultaneously being mapped by the Hydrosweep. The energy from the sub-bottom profiler is directed downward by a 3.5-kHz transducer mounted in the hull of the *Ewing*. The output varies with water depth from 50 watts in shallow water to 800 watts in deep water. Pulse interval is 1 second but a common mode of operation is to broadcast five pulses at 1-s intervals followed by a 5-s pause.

3.5 kHz Sub-bottom Profiler Specifications

Maximum source output (downward)	204 dB re 1 μPa at 800 watts
Normal source output (downward)	200 dB re 1 μPa at 500 watts
Dominant frequency components	3.5 kHz
Bandwidth	1.0 kHz with pulse duration 4 ms
	0.5 kHz with pulse duration 2 ms
	0.25 kHz with pulse duration 1ms
Nominal beam width	30 degrees
Pulse duration	1, 2, or 4 ms

II. DATES, DURATION AND REGION OF ACTIVITY

The date(s) and duration of such activity and the specific geographical region where it will occur.

The project is planned to take place from 8–23 July 2004. The *Ewing* is scheduled to depart for the study area from San Diego, California, on 8 July 2004. Once at the study area, OBS deployments and recoveries will take ~1.3 days; streamer and airgun deployment and recovery will each take ~12 h. Airgun operations are expected to commence on 10 July 2004. The 12-gun array will be operated for 24 hours and the 10-gun array will be operated for 6.5 days, for a total of ~10 days of scientific work at the study area. The airgun arrays, streamer, and OBSs will be recovered at the end of the survey, and the vessel will transit to Astoria, Oregon, for arrival on 23 July 2004.

The main survey is planned to occur near the intersection of the Blanco Transform with the Juan de Fuca Ridge, ~450 km (243 n.mi.) off the coast of Oregon (Fig. 2). The area within which the main seismic survey will occur is located between 44º20' and 44º42'N and between 129º50' and 130º30'W (Fig. 2). A second survey may be conducted, time permitting; that contingency survey would be located at Gorda Ridge between 42º20' and 43ºN and between 126º30' and 127ºW, ~157 km (84 n.mi.) from the coast (Fig. 3). The main seismic survey will take place offshore outside of territorial waters or the Exclusive Economic Zone (EEZ) of any nation, however the contingency survey is located within the EEZ of the U.S.A.

III. Species and Numbers of Marine Mammals in Area

The species and numbers of marine mammals likely to be found within the activity area.

At least 30 cetacean species, 8 pinniped species, and 1 sea otter species (Table 2) may occur or have been documented to occur in the marine waters off Oregon and Washington, including extralimital sightings or strandings (Fiscus and Niggol 1965; Green et al. 1992, 1993; Barlow et al. 1996; Barlow 1997, 2003; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow and Taylor 2001; Buchanan et al. 2001; Calambokidis et al. 2003; Calambokidis and Barlow 2004).

To avoid redundancy, we have included the required information about the species and (insofar as it is known) numbers of these species in Section IV, below.

IV. Status, Distribution and Seasonal Distribution of Affected Species or Stocks of Marine Mammals

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities

Sections III and IV are integrated here to minimize repetition.

Thirty-nine marine mammal species have been documented off Oregon and Washington, including odontocetes (toothed cetaceans, such as dolphins), mysticetes (baleen whales), pinnipeds, and sea otters (Table 2). Six of the species that may occur in the project area are listed under the ESA as "Endangered", including sperm, humpback, sei, fin, blue, and North Pacific right whales. One other species listed as "Threatened" may occur in the project area: the Steller sea lion.

As described in § I, the main Blanco Transform survey site, and the Gorda Ridge contingency survey site, are located ~450 and ~150 km (243 and 81 n.mi.) offshore from Oregon, respectively, over water depths of 1600 to 5000 m or 5250 to 16405 ft (Fig. 1). Based on their preference for offshore (>2000 m depth) and/or slope (200–2000 m or 656–6560 ft) waters, 19 of the 39 marine mammal species known for Oregon and Washington waters are considered likely to occur near the survey areas. An additional 14 species could occur, but are unlikely to do so in the project area because they are rare or uncommon in slope and offshore waters or they generally do not occur off Oregon or Washington. However, these 14 species are addressed in the following section in the unlikely chance that they may occur there. An additional six species are not expected in the project area because their occurrence off Oregon is limited to coastal / shallow waters (gray whale and sea otter) or they are considered extralimital

TABLE 2. The habitat, abundance, and conservation status of marine mammals that may occur in the two proposed seismic study areas located in slope and offshore waters off Oregon. Species that are not known to have been documented off Oregon/Washington, but may occur in the project area, are indicated by two asterisks (**).

Species	Habitat	Abundance (NPO, OR/WA, or other[1])	ESA[2]	IUCN[3]	CITES[4]
Odontocetes					
Sperm whale (*Physeter macrocephalus*)	Usually pelagic and deep seas	24,000 [5] 24,000-39,200 [6] 1233 [7] 440 [8]	Endangered *	Vulnerable	I
Pygmy sperm whale (*Kogia breviceps*)	Deeper waters offshore	4746 [6] 494 [8]	Not listed	NA	II
Dwarf sperm whale (*Kogia sima*)	Deeper waters offshore	NA	Not listed	NA	II
Cuvier's beaked whale (*Ziphius cavirostris*)	Pelagic	20,000 [9] 1884 [7] 0 [8]	Not listed	Data Deficient	II
Baird's beaked whale (*Berardius bairdii*)	Pelagic	6000 [10] 228 [7] 117 [8]	Not listed	Lower Risk/ Conservation Dependent	I
Blainsville's beaked whale** (*Mesoplodon densirostris*)	Slope, offshore	NA	Not listed	Data Deficient	II
Hubb's beaked whale (*Mesoplodon carlhubbsi*)	Slope, offshore	NA	Not listed	Data Deficient	II
Stejneger's beaked whale (*Mesoplodon stejnegeri*)	Slope, offshore	NA	Not listed	Data Deficient	II
Offshore bottlenose dolphin** (*Tursiops truncatus*)	Offshore, slope	5065 [7] 0 [8]	Not listed	Data Deficient	II
Striped dolphin (*Stenella coeruleoalba*)	Offshore, occasionally inshore	13,934 [7] 64 [8]	Not listed	Lower Risk/ Conservation Dependent	II
Short-beaked common dolphin (*Delphinus delphis*)	Continental shelf, pelagic	449,846 [7] 6,316 [8]	Not listed	NA	II*
Pacific white-sided dolphin (*Lagenorhynchus obliquidens*)	Offshore, slope	59,274 [7] 10,934 [8]	Not listed	NA	II
Risso's dolphin (*Grampus griseus*)	Shelf, slope	16,066 [7] 8187 [8]	Not listed	Data Deficient	II
False killer whale (*Pseudorca crassidens*)	Pelagic, occasionally inshore	40,000 [11]	Not listed	NA	II

Species	Habitat	Abundance (NPO, OR/WA, or other[1])	ESA[2]	IUCN[3]	CITES[4]
Killer whale (*Orcinus orca*)	Widely distributed	8500 [6] 1340 [7] 1167 [8]	Not listed	Lower Risk/ Conservation Dependent	II
Short-finned pilot whale (*Globicephala macrorhynchus*)	Inshore, offshore	160,200 [9] 304 [7] 0 [8]	Not listed	Lower Risk/ Conservation Dependent	II
Northern right whale dolphin (*Lissodelphis borealis*)	Slope, offshore waters	20,362 [7] 10,190 [8]	Not listed	NA	II
Harbor porpoise (*Phocoena phocoena*)	Coastal and inland waters	28,967 [6]	Not listed	Vulnerable	II
Dall's porpoise (*Phocoenoides dalli*)	Shelf, slope, offshore	98,617 [7] 76,874 [8]	Not listed	Lower Risk/ Conservation Dependent	II
Mysticetes					
North Pacific right whale (*Eubalaena japonica*)	Inshore, occasionally offshore	<100 [6]	Endangered *	Endangered	I
Humpback whale (*Megaptera novaeangliae*)	Mainly near-shore waters and banks; shelf and slope waters	>6000 [6] 1314 [7] 366 [8] 562 [12] 837 [13]	Endangered *	Vulnerable	I
Minke whale (*Balaenoptera acutorostrata*)	Continental shelf, coastal waters	1015 [7] 411 [8]	Not listed	Lower Risk/ Near Threatened	I
Sei whale (*Balaenoptera borealis*)	Primarily offshore, pelagic	7260-12620 [6, 14] 56 [7] 0 [8]	Endangered *	Endangered	I
Fin whale (*Balaenoptera physalus*)	Continental slope, mostly pelagic	8520-10970 [6, 15] 3279 [7] 380 [8]	Endangered *	Endangered	I
Blue whale (*Balaenoptera musculus*)	Pelagic, coastal	1400-1900 [6, 16] 3000 [17] 1736 [7] 101 [8]	Endangered *	Endangered	I
Pinnipeds					
Northern fur seal (*Callorhinus ursinus*)	Pelagic offshore	941,756 [18]	Not listed	NA	NA
California sea lion (*Zalophus californianus californianus*)	Coastal, shelf	204,000 [18]	Not listed	NA	NA

Species	**Habitat**	**Abundance (NPO, OR/WA, or other[1])**	**ESA[2]**	**IUCN[3]**	**CITES[4]**
Steller sea lion (*Eumetopias jubatus*)	Coastal, shelf	31,028 [18]	Threatened	Endangered	NA
Harbor seal (*Phoca vitulina richardsi*)	Coastal	24,732 [19]	Not listed	NA	NA
Northern elephant seal (*Mirounga angustirostris*)	Coastal, pelagic when migrating	101,000 [18]	Not listed	NA	NA.

NA - Data not available or species status not assessed off Oregon/Washington and/or California in Barlow (2003).
*Listed as a strategic stock under the U.S. Marine Mammal Protection Act.
[1] Abundance estimates for the Eastern Tropical Pacific (ETP).
[2] Endangered Species Act (Carretta et al. 2001, 2002).
[3] IUCN Red List of Threatened Species (2003).
[4] Convention on International Trade in Endangered Species of Wild Fauna and Flora (UNEP-WCMC 2004).
[5] Abundance estimate for eastern temperate North Pacific (Whitehead 2002).
[6] Abundance estimate for U.S. West Coast (Carretta et al. 2002).
[7] Abundance off California/Oregon/Washington (Barlow 2003).
[8] Abundance off Oregon/Washington (Barlow 2003).
[9] Abundance in the ETP (Wade and Gerrodette 1993).
[10] Abundance in Western North Pacific (Reeves and Leatherwood 1994).
[11] Abundance in ETP (Reeves et al. 2002).
[12] Abundance off Washington (Calambokidis et al. 2003).
[13] Abundance estimate for NPO in 1997 by mark-recapture technique (Calambokidis and Barlow 2004).
[14] Abundance in NPO (Tillman 1974).
[15] Abundance in NPO (Ohsumi and Wada 1974).
[16] Abundance in NPO (Klinowska 1991).
[17] Abundance for California/Oregon/Washington (Calambokidis and Barlow 2004).
[18] Abundance for NPO (NOAA 2004).
[19] Abundance for OR/WA coastal stock (NOAA 2004).

(beluga whale and ringed, ribbon, and hooded seals). Those six species are not addressed in detail in the summaries below. Vagrant ringed seals, hooded seals, and ribbon seals have been sighted or stranded on the coast of California (see Mead 1981; Reeves et al. 2002) and presumably passed through Oregon waters. A vagrant beluga whale was seen off the coast of Washington (Reeves et al. 2002).

The six species of marine mammals expected to be most common in the deep pelagic or slope waters of the project area include the Pacific white-sided dolphin, northern right whale dolphin, Risso's dolphin, short-beaked common dolphin, Dall's porpoise, and northern fur seal (Green et al. 1992, 1993; Buchanan et al. 2001; Carretta et al. 2002; Barlow 2003). The sperm whale, pygmy sperm whale, mesoplodont species, Baird's beaked whale, Cuvier's beaked whale, and northern elephant seals are considered pelagic species but are generally uncommon in the waters near the survey area.

Of the five species of pinnipeds known to occur regularly in waters off Oregon, Washington, or northern California, only the northern fur seal and northern elephant seal are likely to be present in the pelagic waters of the proposed project area, located ~150–450 km (243–481 n.mi.) offshore. The Steller sea lion may also occur there in small numbers. The California sea lion and harbor seal occur in shallow coastal or shelf waters off Oregon and Washington (Bonnell et al. 1992; Green et al. 1993; Buchanan et al. 2001), and are not expected to be seen in the proposed study area. Sea otters were translocated to shallow coastal waters off the Olympic Peninsula of Washington, but are not found in the pelagic waters of the project area off Oregon. (The sea otter is the one marine mammal species mentioned in this document that, in the U.S., is managed by the U.S. Fish & Wildlife Service; all others are managed by the NMFS.)

Most of the systematic data on marine mammals in waters off Oregon and Washington have been collected during surveys concentrated primarily in coastal/shelf (<200 m or 656 ft depth) and slope (200–2000 m or 656–6560 ft) waters within ~200 km (108 n.mi.) of the coastline (e.g., Green et al. 1992; Calambokidis et al. 2003). However, several systematic ship and aerial surveys have included deeper waters out to ~556 km (300 n.mi.), predominantly during summer and autumn (Green et al. 1993; Mangels and Gerrodette 1994; Barlow 1995, 1997, 2003; Von Saunder and Barlow 1999).

Studies indicate that the distribution and occurrence of marine mammals off Oregon and Washington are related to water depth, water temperature, season, year, proximity to shore, and oceanographic influences, including El Niño and La Niña events and the California Current (Green et al. 1992, 1993; Barlow 2003; Buchanan et al. 2001; Calambokidis et al. 2003). For example, false killer whales, short-finned pilot whales, striped dolphins, and short-beaked common dolphins appear to occur in Oregon waters during years of very warm water (Green et al. 1993; Buchanan et al. 2001). Pacific white-sided and Risso's dolphins exhibit seasonal shifts in distribution off Oregon and Washington, being most abundant during spring and summer, less so during the fall, and rare during winter, apparently moving south during colder water temperatures (Green et al. 1992, 1993; Buchanan et al. 2001). Inshore–offshore seasonal movements are known for Dall's porpoise which shifts from outer shelf and slope waters to shelf waters during the summer and fall to follow the movements of schooling fish and squid (Fiscus and Niggol 1965). In general, marine mammals off Oregon and Washington that prey primarily on squid or deep-water fish (e.g., sperm whales, beaked whales, Dall's porpoise, fur seals, elephant seals) occur in deep pelagic waters, whereas those that feed largely on schooling pelagic fish or shallow-water squid are distributed closer to shore (e.g., sea lions, harbor porpoise, harbor seals).

In the following section, many references are made to the occurrence and density of cetaceans off the coasts of both Oregon and Washington. That is the geographic area where systematic surveys have been concentrated and where the California Current appears to result in an apparent shift in the distribution, abundance, and occurrence of marine mammal species related to water temperatures (Bonnell et al. 1992; Green et al. 1992, 1993; Buchanan et al. 2001). The primary data used to provide densities for the proposed project area were collected during dedicated shipboard surveys done by the Southwest Fisheries Science Center (SWFSC) of NMFS in 1996 and 2001 off Oregon and Washington ("ORCAWALE" surveys), as synthesized using line-transect methods in Barlow (2003). That report was used to provide densities, because it provides results from the most recent and comprehensive systematic line transect surveys conducted from shallow coastal waters out to ~556 km offshore (300 n.mi.), beyond the 2000 m (6560 ft) depth contour. Those surveys encompass the offshore deep waters of the proposed project sites (Fig. 1).

The 1996 and 2001 ship surveys used by Barlow (2003) followed similar procedures and occurred from mid- or late-July through early November or December to facilitate comparisons between years. Thus, they slightly overlap the July period proposed for the current study. Barlow (2003) incorporated correction factors to account for changes in detectability of species with distance from the survey track line [detectability bias or $f(0)$] and the diving behavior of the animals [availability bias or $g(0)$]. Densities (number of schools per 1000 km surveyed) and co-efficients of variation (CV) were also included in the preliminary Barlow (2003) report.

Odontocetes

Sperm Whale (*Physeter macrocephalus*)

Sperm whales are the largest of the toothed whales, with an extensive worldwide distribution (Rice 1989). They range as far north and south as the edges of the polar pack ice, although they are most abundant in tropical and temperate waters where temperatures are >15ºC (59ºF) (Rice 1989). They are mainly found in pelagic or deep waters.

Sperm whales are distributed widely across the North Pacific (Carretta et al. 2002). Off Oregon, they are seen in every season except winter (Green et al. 1992). In contrast, sperm whales are found off California year-round (Dohl et al. 1983; Barlow 1995; Forney et al. 1995), with a peak abundance from April to mid-June and from August to mid-November (Rice 1974). Barlow and Taylor (2001) estimated sperm whale abundance off California/Oregon/Washington as 1407. Based on surveys conducted in 1996 and 2001, Barlow (2003) estimated the same population at 1233. For just Oregon/Washington waters, Barlow (2003) gave estimates of 440 and 52, based on data from 1996 and 2001, respectively. Densities off the coasts of California/Oregon/Washington range from 0.0002 to 0.0019/km^2, depending on area and year (Barlow 2003).

Sperm whales occur singly (older males) or in groups of up to 50. Christal et al. (1998) noted that typical social unit sizes ranged from 3 to 24. Sperm whale distribution is thought to be linked to social structure. Adult females and juveniles generally occur in tropical and subtropical waters, whereas males are commonly alone or in same-sex aggregations, often occurring in higher latitudes outside of the breeding season (Best 1979; Watkins and Moore 1982; Arnbom and Whitehead 1989; Whitehead and Waters 1990). Mature sperm whales migrate to warmer waters to breed when they are in their late twenties (Best 1979). They typically move between mixed schools, and only spend a short period of time with those groups (Whitehead 1993). Sperm whales are seasonal breeders, but the mating season is prolonged. In the Northern Hemisphere, conception may occur from January to August (Rice 1989), although peak breeding season is from April to June (Best et al. 1984). Females bear a calf every 3–6 years (Rice 1989).

Sperm whales generally are distributed over large areas that have high secondary productivity and steep underwater topography (Jacquet and Whitehead 1996). They routinely dive to depths of hundreds of meters and may occasionally dive to depths of 3000 m or 9843 ft (Rice 1989). They are capable of remaining submerged for longer than two hours, but most dives probably last a half-hour or less (Rice 1989). The diet of sperm whales consists mainly of mesopelagic and benthic squids and fishes, and the daily food requirement for sperm whales ranges from several hundred to several thousand kilograms (Best 1979).

Sperm whales produce acoustic clicks when underwater, probably for locating prey and for communication (Backus and Schevill 1966; Møhl et al. 2003). In the Galapagos Islands, sperm whales started to click regularly when they were 150–300 m (492–984 ft) deep (Papastavrou et al. 1989), which may indicate that the sperm whales were echolocating for food at those depths (Backus and Schevill 1966; Weilgart and Whitehead 1988; Smith and Whitehead 1993). On the breeding grounds, mature males produce "slow clicks" (Whitehead 1993) in the frequency range 0.1–30 kHz (review by Thomson and Richardson 1995).

The sperm whale is the one species of odontocete discussed here that is listed under the ESA, and the one species of odontocete that is listed in CITES Appendix I (Table 2). Although the species is formally listed as ***Endangered*** under the ESA, it is a relatively common species on a worldwide basis, and is not biologically endangered.

Pygmy Sperm Whale (*Kogia breviceps*) and Dwarf Sperm Whale (*Kogia sima*)

These two species of small whales are distributed widely in the world's oceans, but they are poorly known (Caldwell and Caldwell 1989). Their small size, non-gregarious nature, and cryptic behavior make pygmy and dwarf sperm whales difficult to observe. The two species are also difficult to distinguish when sighted at sea, and are often jointly categorized as *Kogia* spp. For waters off California, Oregon, and Washington, Barlow (1997) used data collected in 1991–1996 to estimate an abundance of 2933 pygmy sperm whales plus 1813 unidentified *Kogia* spp. However, because no dwarf sperm whales have been identified on the west coast since the early 1970s, it seems likely that the unidentified species are all pygmy sperm whales, bringing the abundance estimate up to 4746 (Carretta et al. 2002). No *Kogia* spp. were seen during surveys in 2001, but Barlow (1997) estimated an abundance of 494 for Oregon/Washington based on data from 1996.

Dwarf and pygmy sperm whales are sighted primarily along the continental shelf edge and over deeper waters off the shelf (Hansen et al. 1994; Davis et al. 1998). However, along the U.S. West Coast (USWC), sightings of the whales have been rare, although that is likely a reflection of their pelagic distribution and small size rather than their true abundance (Carretta et al. 2002). Barros et al. (1998) suggested that dwarf sperm whales might be more pelagic and dive deeper than pygmy sperm whales. Pygmy sperm whales mainly feed on various species of squid in the deep zones of the continental shelf and slope (McAlpine et al. 1997). Pygmy sperm whales occur in small groups of up to six, and dwarf sperm whales may form groups of up to 10 (Caldwell and Caldwell 1975). Barlow (2003) noted a mean group size of 1.

Strandings of pygmy sperm whales have been recorded for California, Oregon and Washington (Caldwell and Caldwell 1989). Although there are few useful estimates of abundance for pygmy or dwarf sperm whales anywhere in their range, they are thought to be fairly common in some areas (Jefferson et al. 1993; Carwardine 1995). Barlow (2003) noted a density of 0.0015/km^2 off Oregon/Washington and 0.0009/km^2 off California.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

This cosmopolitan species is probably the most widespread of the beaked whales, although it is not found in polar waters (Heyning 1989). It appears to be absent from areas north of 60ºN and south of 50ºS (Würsig et al. 2000). It is the most common beaked whale off the USWC (Carretta et al. 2002). The abundance estimate for California, Oregon, and Washington waters, based on data from 1991–1996, was 5870 (Barlow 1997), and for data collected in 1996 and 2001, it was estimated as 1884 (Barlow 2003). No Cuvier's beaked whales were seen during the Oregon/Washington portions of the surveys in 1996 or 2001 (Barlow 2003), but several animals were seen there from 1991 to 1995 (Barlow 1997). Densities for California waters range from 0.0023 to 0.0102/km^2 (Barlow 2003).

Cuvier’s beaked whales are rarely found close to mainland shores, except in submarine canyons or in areas where the continental shelf is narrow and coastal waters are deep (Carwardine 1995). Mostly pelagic, this species appears to be confined to the warmer side of the 10°C isotherm and the deeper side of the 1000-m (3281-ft) bathymetric contour (Houston 1991; Robineau and di Natale 1995). Its inconspicuous blow, deep-diving behavior, and tendency to avoid vessels may help explain the rarity of sightings. Adult males usually travel alone, but Cuvier's beaked whales can be seen in groups of up to 25. Calves are born year-round (Würsig et al. 2000). The species occurs offshore, and typically dives for 20–40 min in water up to 1000 m (3281 ft) deep. The stomach contents of stranded animals are primarily cephalopods, with occasional crustaceans and fish (Debrot and Barros 1994; MacLeod et al. 2003).

Cuvier's beaked whale is mostly known from strandings (Leatherwood et al. 1976; NOAA and USN 2001). There are more recorded strandings for Cuvier's beaked whale than for any other beaked whale (Heyning 1989). Causes of the strandings are unknown, but they likely include old age, illness, disease, pollution, exposure to certain strong noises, and perhaps geomagnetic disturbance. Mass strandings of Cuvier's beaked whales are rare (although individual strandings are quite common), with only seven documented cases of more than four individuals stranding between 1963 and 1995 (Frantzis 1998). In May 1996, 12 Cuvier's beaked whales stranded along the coasts of Kyparissiakos Gulf in the Mediterranean Sea. That stranding was subsequently linked to the use of low- and medium-frequency active sonar by a North Atlantic Treaty Organization (NATO) research vessel in the region (Frantzis 1998). In March 2000, a population of Cuvier's beaked whales being studied in the Bahamas disappeared after a U.S. Navy task force using mid-frequency tactical sonars passed through the area; some beaked whales stranded (Balcomb and Claridge 2001; NOAA and USN 2001). In September 2002, a total of 14 beaked whales (7 *Ziphius cavirostris*, 1 *Mesoplodon europaeus*, 3 *Mesoplodon densirostris*, and 3 undetermined beaked whales) stranded coincident with naval exercises in the Canary Islands (Martel n.d.; Jepson et al. 2003). Also in September 2002, two stranded Cuvier's beaked whales were discovered at Isla San Jose in the Gulf of California, coincident with geophysical survey operations being conducted by the R/V *Maurice Ewing*. Section IV (a) discusses those strandings.

Baird's Beaked Whale (*Berardius bairdii*)

Baird's beaked whales have a fairly extensive range across the North Pacific, with concentrations occurring in the Sea of Okhotsk and Bering Sea (Rice 1998; Kasuya 2002). In the eastern Pacific, Baird's beaked whales are reported to occur as far south as San Clemente Island, California (Rice 1998; Kasuya 2002). It has been proposed that Baird's beaked whales can be divided into three distinct stocks: a Sea of Japan stock, an Okhotsk Sea stock, and a Bering Sea/eastern North Pacific stock (Balcomb 1989; Reyes 1991). Any animals in the vicinity of the study area would be expected to come from the Bering Sea/eastern Pacific stock. For California/Oregon/Washington waters, Barlow (1997) estimated an abundance of 379 Baird's beaked whales based on survey data collected in 1991–96. Barlow (2003) gave an abundance estimate of 228 based on data from 1996 and 2001. Abundance estimates for Oregon and Washington waters were estimated as 64 in 1996 and 117 in 2001 (Barlow 2003). Density estimates for waters off Oregon/Washington ranged from 0.0002 to 0.0004/km^2, and densities off California ranged up to 0.0009/km^2.

Baird's beaked whales sometimes are seen close to shore, but their primary habitat is over or near the continental slope and oceanic seamounts (Jefferson et al. 1993). Along the USWC, they have been sighted primarily along the continental slope (Green et al. 1982; Carretta et al. 2002). Information gathered from sightings on both sides of the North Pacific indicates that Baird's beaked whales are present over the continental slope in summer and autumn, when water temperatures are highest. The whales move out from those areas in winter (Reyes 1991). In the NPO, Baird's beaked whales apparently spend the winter and spring far offshore, and in June they move onto the continental slope, where peak numbers occur during September and October. Green et al. (1992) noted that Baird's beaked whales on the USWC were most abundant in the summer, and were not sighted in the fall or winter.

Baird's beaked whales feed on deep-water and bottom-dwelling fish, cephalopods, and crustaceans (Jefferson et al. 1993), and some pelagic fish (Reyes 1991; Kasuya 2002). Typical water depths for sightings are 1000–3000 m (3281–9843 ft). Baird's beaked whales can stay submerged for up to 67 min (Kasuya 2002). That makes it very difficult to sight and to visually track them. Baird's beaked whales live in pods of 5–20, although larger groups are sometimes seen. There appears to be a calving peak in March and April (Jefferson et al. 1993).

***Mesoplodon* spp.**

Three species of *Mesoplodon* may occur off the coasts of Oregon and Washington: Blainville's beaked whale (*M. densirostris*), Stejneger's beaked whale (*M. stejnegeri*), and Hubb's beaked whale (*M. carlhubbsi*). In addition, records exist for Hector's beaked whales (*M. hectori*) and Ginkgo-toothed beaked whales (*M. ginkgodens*) off the coast of California (Mead 1981). However, those species are unlikely to be seen in the proposed study area, and will not be discussed further.

Mesoplodonts are difficult to distinguish in the field. For California/Oregon/Washington, Barlow (1997) estimated an abundance of 3738 for mesoplodont beaked whales of unknown species, and 360 Blainville's beaked whales. In 1996, the estimated abundance of mesoplodont beaked whales was 2169 for Oregon and Washington, but in 2001 it was zero (Barlow 2003). Barlow (2003) noted a density of 0.0067/km^2 for Oregon/Washington and densities up to 0.002/km^2 for waters off California.

Mesoplodonts are pelagic, spending most of their time in deep water far from shore, and are little known. Mesoplodonts feed on squid, other cephalapods, and fish. Dives can be long, exceeding 45 min for *M. densirostris*. Mesoplodonts are generally seen alone or in small groups.

Blainville's beaked whale is the *Mesoplodon* species with the widest distribution throughout the world (Mead 1989), although it is generally limited to tropical and warmer temperate waters (Leatherwood and Reeves 1983). Occasional occurrences in cooler higher-latitude waters are presumably related to warm-water incursions (Reeves et al. 2002). In the NPO, the northernmost documented occurrence of this species is a stranding off central California (Reeves et al. 2002). Seasonal movements or migrations by Blainville's beaked whales are not known to occur. It is unlikely to be present in the study area, as its main distribution is south of the proposed project area.

Blainville's beaked whale distribution is mainly derived from stranding data. It is mainly a pelagic species, and like other beaked whales, is generally found in deep slope waters roughly 500–1000 m or 1600 to 3300 ft deep (Davis et al. 1998; Reeves et al. 2002). However, it may also occur in coastal areas, particularly where deep water gullies come close to shore. Most strandings involved single individuals, although groups of 3 to 7 were observed in tropical waters (Jefferson et al. 1993). Ritter and Brederlau (1999) estimated group size to range from 2 to 9 (mean 3.44). In September 2002, three Blainville's beaked whales stranded in a group of 14 beaked whales in an incident that was subsequently linked to naval exercises in the Canary Islands region (Martel n.d.).

Stejneger's beaked whale occurs in subarctic and cool temperate waters of the North Pacific (Mead 1989). In the NPO, it is distributed from Alaska to southern California (Mead et al. 1982; Mead 1989). However, most records are from Alaskan waters, and the Aleutian Islands appear to be its center of distribution (Mead 1989). Small groups have been known to strand at the Aleutian Islands (Mead 1989). This species occurs in groups of 3 to 4, ranging to ~15 (Reeves et al. 2002).

Hubb's beaked whale occurs in temperate waters of the North Pacific (Mead 1989). Most of the records are from California, but this species has been sighted as far north as Prince Rupert, British Columbia (Mead 1989). The distribution of the species appears to be correlated with the deep subarctic current (Mead et al. 1982). Hubb's beaked whales are often killed in drift gillnets off California (Reeves et al. 2002).

Bottlenose Dolphin (*Tursiops truncatus*)

The bottlenose dolphin is distributed worldwide and is considered possibly the most adaptable species of cetacean, inhabiting a wide range of habitat types (Reeves et al. 2002). There are two distinct types: a shallow-water type mainly found in coastal waters, and a deep-water type mainly found in oceanic waters (Duffield et al. 1983; Walker et al. 1999). In the proposed study area, it is possible that offshore bottlenose dolphins could be encountered during warm-water periods (see Carretta et al. 2002), although none have been sighted in waters off Oregon or Washington. Although they occur more frequently off the coast of California, sightings have been made as far north as 41ºN (Carretta et al. 2002). The abundance estimate of offshore bottlenose dolphins for California/Oregon/Washington is 956, with all of these being off California.

Striped Dolphin (*Stenella coeruleoalba*)

Striped dolphins have a cosmopolitan distribution in tropical to warm temperate waters (Perrin et al. 1994). Striped dolphins are pelagic, and seem to prefer the deep water along the edge and seaward of the continental shelf (Davis et al. 1998). Off California, they have been sighted within 185–556 km (100–300 n.mi.) of the coast (Carretta et al. 2002). However, they do occur in coastal waters (Isaksen and Syvertsen 2002). Few sightings have been reported for Oregon or Washington, with the exception of a survey by Barlow (2003) in 1996; several strandings are known for that area (see Carretta et al. 2002). Although it is unlikely that the species will occur in the proposed seismic study area, it could be encountered in the contingency survey area, as that site is situated farther to the south. The 1991–96 average abundance estimate for California/Oregon/Washington is 20,235 (Barlow 1997). Barlow (2003) estimated the abundance as 13,934 for that same area. For waters off Oregon/Washington, Barlow (2003) gave an abundance estimate of 64, based on data collected in 1996.

Striped dolphins prey on small fish and small cephalopods (Perrin et al. 1994). They are gregarious (groups of 20 or more are common) and active at the surface (Whitehead et al. 1998). School composition varies and consists of adults, juveniles, or both adults and juveniles (Perrin et al. 1994). Their breeding season has two peaks, one in the summer and one in the winter (Boyd et al. 1999). Gestation lasts about a year, and females nurse their calves for four years (Perrin et al. 1994). Striped dolphins produce sounds at 6–24 kHz (review by Thomson and Richardson 1995).

Short-beaked Common Dolphin (*Delphinus delphis*)

Common dolphins are found in tropical and temperate oceans around the world (Evans 1994). There are two species: the short-beaked common dolphin (*D. delphis*) and the long-beaked common dolphin (*D. capensis*). Prior to the early 1990s, short-beaked and long-beaked common dolphins were not treated as separate species, and most of the earlier literature refers to all common dolphins combined. Only short-beaked dolphins may occur in the project area, although their occurrence there is unlikely. Short-beaked common dolphins are the most abundant cetacean off California, but they are rare off Oregon and Washington (Carretta et al. 2002). Long-beaked common dolphins are not found north of central California (Carretta et al. 2002).

The distribution of short-beaked common dolphins along the USWC is variable and likely related to oceanographic changes (Heyning and Perrin 1994; Forney and Barlow 1998). Barlow (1997) estimated an abundance of 373,573 for California/Oregon/Washington using data collected in 1991-96. Barlow (2003) estimated an abundance of 449,846 for that same region, based on data collected in 1996 and

2001. The abundance estimates for waters off Oregon/Washington alone were 6316 and 398 animals for 1996 and 2001, respectively. Densities of short-beaked common dolphins range from 0.0012 to 0.0194/km^2 off Oregon/Washington and up to 0.6323/km^2 off California.

Common dolphins often travel in fairly large groups; schools of hundreds or even thousands are common. Groups are composed of subunits of 20–30 closely related individuals (Evans 1994). Scott and Cattanach (1998) noted that they form larger groups in the morning and smaller groups in the later afternoon and night. Perryman and Lynn (1993) determined that, for central common dolphins, births occurred throughout the year. For southern common dolphins, births only occurred from January to July. Their principal prey includes small schooling fish such as hake, sardines, and anchovies (Evans 1994). Like other dolphins, they are highly vocal (Evans 1994), and echolocate using ultrasonic pulsed signals. They produce sounds at 2–18 kHz and ultrasounds at 23–67 kHz (review by Thomson and Richardson 1995).

Pacific White-sided Dolphin (*Lagenorhynchus obliquidens*)

The Pacific white-sided dolphin is found in cool temperate waters of the North Pacific from the southern Gulf of California along the western coast of North America north to Alaska. Across the North Pacific, it appears to have a relatively narrow distribution between 38°N and 47°N (Brownell et al. 1999). In the NPO, including waters off Oregon, the Pacific white-sided dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters (Green et al. 1993; Barlow 2003). It is mainly found offshore, beyond the continental shelf, but does come closer to shore where there is deep water, such as over submarine canyons (Carwardine 1995). It is known to occur close to shore in certain regions, including (seasonally) southern California (Brownell et al. 1999).

Results of recent aerial and shipboard surveys strongly suggest seasonal north–south movements of the species between California and Oregon/Washington. These movements are apparently related to oceanographic influences, particularly water temperature (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001; Carretta et al. 2002). During winter, this species is most abundant in California slope and offshore areas; as northern marine waters begin to warm in the spring, it appears to move north to slope and offshore waters off Oregon/Washington (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). Seasonal abundance estimates off the entire coast of California are an order of magnitude higher in February–April than in August–November, whereas the highest abundance estimates off Oregon and Washington are in April–May.

Extensive year-round aerial surveys off Oregon/Washington conducted by Green et al. (1992, 1993) found that the Pacific white-sided dolphin was the most abundant cetacean species, with nearly all (97%) sightings occurring in May. Encounter rates during May of 1989–1990 and 1992 were 250, 45, and 714/1000 n.mi., respectively, with the highest rate associated with a 1992 El Niño event (Green et al. 1993). During March–May, encounter rates in slope waters varied from 131 to 633/1000 n.mi., and in offshore waters from 224 to 451, with the highest rates again associated with the 1992 El Niño year. In addition, mean group sizes were significantly higher in slope (11.6) vs. offshore waters (6.7). Barlow (2003) also found that *L. obliquidens* was the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys, reporting corrected densities of 0.027 and 0.034/km^2, respectively. Associated abundance estimates for 1996 and 2001 off Oregon/Washington were 8683 and 10,934.

Pacific white-sided dolphins are very gregarious and commonly occur in groups of 10–100, and occasionally in schools of thousands (Reeves et al. 2002). They often associate with other species, including cetaceans, pinnipeds, and seabirds. In particular, they are frequently seen in mixed-species schools with Risso's and northern right whale dolphins (Green et al. 1993). Calving appears to occur primarily in late spring and summer from April to August (Reeves et al. 2002). They are opportunistic feeders, foraging on small schooling fish and small mesopelagic fish and cephalopods associated with the deep scattering layer (DSL) in offshore and very deep coastal waters (Reeves et al. 2002). Feeding is presumed to occur primarily at night when the DSL approaches the surface. Pacific white-sided dolphins are very inquisitive and may approach stationary boats (Carwardine 1995). They area highly acrobatic, commonly bowride, and often leap, flip, or somersault (Jefferson et al. 1993).

Northern Right Whale Dolphin (*Lissodelphis borealis*)

The northern right whale dolphin is found in cool temperate and sub-arctic waters of the North Pacific, from the Gulf of Alaska to near northern Baja California, ranging from 30°N to 50°N (Reeves et al. 2002). In the NPO, including waters off Oregon, the northern right whale dolphin is one of the most common marine mammal species, occurring primarily in shelf and slope waters ~100 to >2000 m, or 328 to >6562 ft deep (Green et al. 1993; Carretta et al. 2002; Barlow 2003). The northern right whale dolphin does, however, come closer to shore where there is deep water, such as over submarine canyons (Carwardine 1995; Reeves et al. 2002).

As in the case of the Pacific white-sided dolphin, recent aerial and shipboard surveys suggest seasonal inshore–offshore and north–south movements in the NPO between California and Oregon/Washington; the movements are believed to be related to oceanographic influences, particularly water temperature and presumably prey distribution and availability (Green et al. 1993; Forney and Barlow 1998; Buchanan et al. 2001; Carretta et al. 2002). However, the seasonal abundance of northern right whale dolphins off Oregon and Washington differs from that of Pacific white-sided and Risso's dolphins. Green et al. (1992, 1993) found that northern right whale dolphins were most abundant off Oregon/Washington during the fall, with low abundance during spring and summer and none occurring there during the winter, when this species presumably moves south to warmer California waters (Green et al. 1992, 1993; Forney 1994; Forney et al. 1995; Buchanan et al. 2001; Barlow 2003). Considerable interannual variations in abundance also have been found.

Extensive year-round aerial surveys off Oregon/Washington conducted by Green et al. (1992, 1993) found that the northern right whale dolphin was the third most abundant cetacean species, concentrated in slope waters but also occurring in waters out to ~556 km (300 n.mi.) offshore. Encounter rates during summer, when the seismic surveys are proposed to occur, were 2.52/1000 km in slope waters and zero in shelf and offshore waters (Green et al. 1992). Barlow (2003) also found that *L. borealis* was one of the most abundant marine mammal species off Oregon/Washington during 1996 and 2001 ship surveys. He reported corrected densities of 0.016 and 0.031/km^2, respectively. Associated abundance estimates for 1996 and 2001 off Oregon/Washington were 5026 and 10,190, respectively.

Northern right whale dolphins are gregarious and groups of several hundred to over a thousand dolphins are not uncommon (Reeves et al. 2002). They are often seen in mixed-species schools with Pacific white-sided dolphins. Calving appears to occur primarily in July and August (Reeves et al. 2002). The species is closely associated with the DSL and presumably feeds primarily at night on small fish, particularly lanternfish, and squid that migrate vertically in the water column. Northern right whale dolphins are known to bowride but they also sometimes swim away from ships (Reeves et al. 2002).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphin is primarily a tropical and mid-temperate species distributed worldwide between 60ºN and 60ºS, where surface water temperatures are ~10ºC (Kruse et al. 1999). Risso's dolphins are pelagic, occurring mostly in continental slope and shelf edge waters (Carretta et al. 2002). Based on extensive year-round aerial surveys off Oregon/Washington out to ~556 km (300 n.mi.) offshore, Risso's dolphins usually occur over steeper sections of the upper continental slope, and are rare in offshore waters >2000 m (6562 ft) deep (Green et al. 1992, 1993).

Throughout the region from California to Washington, the distribution and abundance of Risso's dolphins are highly variable, presumably in response to changing oceanographic conditions on both annual and seasonal time scales (Forney and Barlow 1998; Buchanan et al. 2001; Carretta et al. 2002). Water temperature appears to be an important factor affecting the distribution of Risso's dolphins (Kruse et al. 1999 and refs. therein). Similar to the Pacific white-sided dolphin, Risso's dolphins are believed to make seasonal north-south movements related to water temperature, spending colder winter months off California and moving north to waters off Oregon/Washington during the spring and summer as the northern waters begin to warm (Green et al. 1992, 1993; Buchanan 2001; Barlow 2003). In California, during periods of warm water, increasing numbers of Risso's dolphins and a shoreward shift in their distribution have been observed (Kruse et al. 1999).

Off Oregon/Washington, Risso's dolphins are most abundant over continental slope and shelf waters during spring and summer, less so during fall, and rare during the winter months (Green et al. 1992, 1993). Green et al. (1992, 1993) found that 89% of all Risso's dolphin groups sighted were seen during May, based on year-round aerial surveys covering waters out to ~556 km (300 n.mi.) offshore. Of these sightings, 94% occurred in slope waters 200–2000 m (656–6562 ft) deep; 79% were observed off Oregon, primarily from ~45^o to 47^{o}N. Encounter rates during summer in slope and offshore waters during the same season and depths where the proposed seismic sites are located were 85 and 0/1000 km, respectively (Green et al. 1992). More recent ship surveys out to ~556 km (300 n.mi.) offshore Oregon/Washington in 1996 and 2001 showed densities of 0.025 and 0.018/km^2, respectively (Barlow 2003). Associated abundance estimates for 1996 and 2001 off Oregon/Washington were 8187 and 5917, respectively.

Risso's dolphins occur individually or in small- to moderate-sized groups, normally ranging in numbers from 2 to <250, although groups as large as 4000 have been sighted. The majority of groups consist of <50 individuals (Kruse et al. 1999). Off Oregon/Washington, they appear to calve in the spring off Oregon/Washington (Green et al. 1993). Risso's dolphins prey exclusively on squid which are abundant in the slope currents (Buchanan et al. 2001). They use sounds ranging from 0.1 to 8 kHz and ultrasounds up to 65 kHz (review by Thomson and Richardson 1995).

False Killer Whale (*Pseudorca crassidens*)

False killer whales are found in all tropical and warmer temperate oceans, especially in deep offshore waters (Odell and McClune 1999). Although they are not likely to be seen in the study area, they could potentially occur in the area during a warm-water year (Buchanan et al. 2001).

False killer whales are primarily seen in deep, offshore waters, although sightings have been reported for shallow (<200 m or <656 ft) waters. They are gregarious, and form strong social bonds (Stacey and Baird 1991). They travel in pods of 20–100 (Baird 2002), although groups of several hundreds are sometimes observed. False killer whales feed primarily on fish and cephalopods, but have been known to attack small cetaceans, California sea lions (S.A. MacLean, LGL Alaska, pers. comm.), and even a humpback whale (Jefferson et al. 1993).

Killer Whale (*Orcinus orca*)

Killer whales are cosmopolitan and are fairly abundant globally. They occur from equatorial regions to the polar pack ice, and they may even ascend rivers. They are most common in high latitudes, especially in cooler areas where productivity is high. Along the USWC, killer whales occur from Alaska (Braham and Dahlheim 1982) south to California (Green et al. 1992; Barlow 1995, 1997; Forney et al. 1995). The greatest abundance is found within 800 km (432 n.mi.) of major continents (Mitchell 1975).

Killer whales are segregated socially, genetically, and ecologically into three distinct groups: residents, transients, and offshore animals. Group sizes of resident pods range from 5 to 50, whereas transient pods include 1 to 7 animals (Bigg et al. 1987). Green et al. (1992) noted that most pods seen during their surveys off Oregon and Washington were likely transients. During those surveys, killer whales were sighted only in shelf waters. Offshore killer whales have been sighted off the coasts of California, Oregon and southern Alaska; offshore whales do not appear to mix with the other types of killer whales (Black et al. 1997; Dahlheim et al. 1997). Barlow (1997) estimated the number of killer whales within 556 km (300 n.mi.) of the coasts of California/Oregon/Washington to be 819, of which perhaps 285 were offshore whales (Carretta et al. 2002). Barlow (2003) noted an abundance of 1340 off California/Oregon/Washington with abundance estimates of 420 and 1167 for 1996 and 2001, respectively, for just Oregon/Washington waters. Barlow (2003) noted densities ranging up to 0.0007/km^2 for California waters and 0.0036/km^2 for Oregon/Washington waters.

Killer whales are large and conspicuous, often traveling in close-knit matrilineal groups of a few to tens of individuals (Dahlheim and Heyning 1999). Killer whales appear to prefer coastal areas, but are also known to occur in deep water (Dahlheim and Heyning 1999). Resident groups feed nearly exclusively on fish, whereas transients feed exclusively on marine mammals. Offshore killer whales are less known, and their feeding habits are not strictly defined. Killer whale movements generally appear to follow the distribution of prey.

Killer whales are capable of hearing high-frequency sounds, which is related to their use of high-frequency sound for echolocation (Richardson 1995). They produce whistles and calls in the frequency range of 0.5–25 kHz (review by Thomson and Richardson 1995), and their hearing ranges from below 500 Hz to 120 kHz (Hall and Johnson 1972; Bain et al. 1993).

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

The short-finned pilot whale inhabits tropical and warm temperate waters (Leatherwood and Reeves 1983; Bernard and Reilly 1999). Short-finned pilot whales were common off southern California (Dohl et al. 1980) until an El Niño event occurred in 1982–83 (Carretta et al. 2002). Few sightings were made off California/Oregon/Washington in 1984–1992 (Green et al. 1992; Carretta and Forney 1993; Barlow 1997), and sightings remain rare (Barlow 1997; Buchanan et al. 2001). Thus, short-finned pilot whales are unlikely to be seen in the study area. The abundance of pilot whales in waters off California, Oregon, and Washington is variable, and likely related to oceanographic conditions (Forney and Barlow 1998). Barlow (1997) used survey data from 1991–96 to estimate an abundance of 970 in the area, including sightings off Oregon and Washington. No short-finned pilot whales were seen during surveys off Oregon and Washington in 1989–1990, 1992, 1996 or 2001, but Barlow (2003) noted an abundance of 608 from surveys off California in 1996. Densities off California ranged from 0.0003 to 0.0007/km^2.

The short-finned pilot whale is mainly pelagic and occurs in moderately deep waters (Davis et al. 1998). It usually inhabits waters ~1000 m (3281 ft) deep, where it feeds on squid. It is generally nomadic, but may be resident in certain locations, including California and Hawaii (Olson and Reilly 2002). Changes in the distribution of the short-finned pilot whale likely are influenced by the distribution of its prey. The species is very social and is usually seen in large groups of up to 60. Pilot whale pods are composed of individuals with matrilineal associations (Olson and Reilly 2002). They strand frequently.

Pilot whales exhibit great sexual dimorphism; males are longer than females, have a more pronounced melon, and a larger dorsal fin (Olson and Reilly 2002). They produce whistles with dominant frequencies of 2–14 kHz (review by Thomson and Richardson 1995).

Porpoises

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise inhabits shallow coastal and inland waters but not the deep offshore waters where the planned seismic survey will occur (Carretta et al. 2002; Reeves et al. 2002). Along the USWC, it ranges from Point Barrow, Alaska, to central California (Carretta et al. 2002). Based on year-round surveys spanning coastal to offshore waters of Oregon/Washington, Green et al. (1992) reported that 96% of harbor porpoise sightings occurred in coastal waters <100 m (328 ft) deep, with a few sightings made on the slope near the 200-m (656 ft) isobath. During summer, the reported encounter rates decreased notably from inner shelf to offshore waters. In slope and offshore waters from Newport to Cape Blanco, Oregon, encounter rates were 1.0 and 0.0/1000 km, respectively (that region encompasses the two proposed survey sites). Summer encounter rates in inner and outer shelf waters were considerably higher at 32.7 and 24.7/1000 km, respectively (Green et al. 1992). The corrected abundance estimate for the harbor porpoise off Oregon/Washington out to water depths of 200 m (656 ft) is 39,586 (Laake et al. 1998; Carretta et al. 2002).

Harbor porpoises feed primarily near the seafloor but also within the water column, consuming schooling fish such as herring, capelin, sprat, and silver hake (Reeves et al. 2002). They also prey on squid and octopus, and their seasonal changes in abundance and distribution may be related to the movements of squid (Green et al. 1992). Harbor porpoises tend to be solitary but are very mobile; they have home range sizes of thousands of square miles and often travel many miles per day (Reeves et al. 2002).

Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoise is widely distributed in cool temperate waters of the North Pacific from the U.S.–Mexico border north to the Bering Sea, ranging from ~32ºN to 65ºN (Reeves et al. 2002). Off Oregon and Washington, it is widely distributed over shelf and slope waters, with concentrations near shelf edges, but is also commonly sighted in pelagic offshore waters (Morejohn 1979; Green et al. 1992; Carretta et al. 2002). Combined results of various surveys out to ~556 km (300 n.mi.) offshore indicate that the distribution and abundance of Dall's porpoise varies between seasons and years. North–south movements are believed to occur between Oregon/Washington and California in response to changing oceanographic conditions, particularly temperature and distribution and abundance of prey (Green et al. 1992, 1993; Mangels and Gerrodette 1994; Barlow 1995; Forney and Barlow 1998; Buchanan et al. 2001). The abundance and distribution of *P. dalli* off Oregon/Washington also appears to shift from slope to shelf waters during the fall in pursuit of schooling fish and squid; during the winter, they move offshore again to slope waters (Fiscus and Niggol 1965; Green et al. 1992).

Encounter rates reported by Green et al. (1992) during aerial surveys off Oregon/Washington were highest in the fall (8.21/1000 km), lowest during the winter (4.79), and intermediate during spring and summer (5.53 and 6.39, respectively). With respect to depth, encounter rates in this region during the summer (when the two seismic surveys are proposed to occur) were similarly high in slope and shelf waters (6.66 and 6.84/1000 km), and somewhat lower in offshore waters (4.56). Dall's porpoise was the most abundant species sighted off Oregon/Washington during more recent 1996 and 2001 ship surveys up to ~556 km (300 n.mi.) from shore (Barlow 2003). Reported corrected densities of *P. dalli* during those surveys were 0.24 and 0.025/km^2, respectively. Associated abundance estimates for 1996 and 2001 off Oregon/Washington were 76,874 and 8213, respectively.

Dall's porpoise usually occurs in small groups of 2 to 12 individuals characterized by fluid associations (Reeves et al. 2002). It is a common bowrider, although mothers with calves appear to avoid vessels. Calves are born between early spring and early fall, with most born from June to August. A high percentage of the Dall's porpoise diet consists primarily of small schooling fish, such as herring and hake, squid, and other species associated with the DSL (Reeves et al. 2002).

Mysticetes

North Pacific Right Whale (*Eubalaena japonica*)

The North Pacific right whale is ***Endangered*** under the ESA, and is considered by NMFS (1991) to be the most endangered baleen whale in the world. Although protected from commercial whaling since 1935, there has been little indication of recovery. The pre-exploitation stock may have exceeded 11,000 animals (NMFS 1991). Wada (1973) estimated a total population of 100–200 in the North Pacific based on sighting data. Rice (1974) stated that only a few individuals remained in the eastern North Pacific stock. A reliable estimate of abundance is not available, but is likely <100 individuals. Because of the small population size and the fact that North Pacific right whales migrate north during the spring to spend the summer feeding in high latitudes (see below), it is unlikely that even small numbers will be present in the proposed study area during the planned period of operations in July.

North Pacific right whales summer in the northern North Pacific and Bering Sea, apparently feeding off southern and western Alaska from May to September (e.g., Tynan et al. 2001). The wintering areas for that population are unknown, but have been suggested to include the Hawaiian Islands and the Ryukyu Islands (Allen 1942; Banfield 1974; Gilmore 1978; Reeves et al. 1978; Herman et al. 1980). In April 1996, a right whale was sighted off Maui, reflecting the first documented sighting of a right whale in Hawaiian waters since 1979 (Herman et al. 1980; Rowntree et al. 1980).

Whaling records indicate that right whales once ranged across the entire North Pacific north of 35ºN and occasionally occurred as far south as 20ºN. Although right whales were historically reported off the coast of Oregon, occasionally in large numbers (Scammon 1874; Rice and Fiscus 1968), extensive shore-based and pelagic commercial whaling operations never took large numbers of the species south of Vancouver Island (Rowlett et al. 1994). Nonetheless, Gilmore (1956) proposed that the main wintering ground for North Pacific right whales was off the Oregon coast and possibly northern California, postulating that the inherent inclement weather in those areas discouraged winter whaling (Rice and Fiscus 1968).

In the NPO south of 50ºN, only 29 reliable sightings were recorded from 1900 to 1994 (Scarff 1986; Scarff 1991; Carretta et al. 1994). Rowlett et al. (1994) photographically identified one right whale 65 km (35 n.mi.) west of Cape Elizabeth, Washington, on 24 May 1992 near 47º17'N and 125º11'W over water depths of ~1200 m (3937 ft); the same whale was subsequently photographically identified again ~6 h later 48 km (26 n.mi.) to the west over water depths of ~500 m (1641 ft). Despite many miles of systematic aerial and ship-based surveys for marine mammals off the coasts of Oregon/Washington/California over the years, only seven documented sightings of right whales were made from 1990 to 2000 (Waite et al. 2003).

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale has a cosmopolitan distribution. Although it is considered to be largely a coastal species, it often traverses deep pelagic areas while migrating. Its migrations between high-latitude summering grounds and low-latitude wintering grounds are reasonably well known (Winn and Reichley 1985). The worldwide population of humpback whales is divided into northern and southern ocean populations (Mackintosh 1965). Calambokidis and Barlow (2004) noted that humpback whale abundance off the USWC and Mexico increased from 1991 to 1997, with the best estimates for those years being 569 to 837. The population size of the entire North Pacific humpback whale stock is estimated at more than 6000 (Calambokidis et al. 1997; NMFS 2002), but under the U.S. provisions, it is officially considered an ***Endangered*** species.

The major wintering areas for the species in the North Pacific are (1) the west coast of Baja California, Gulf of California, mainland Mexican coast from southern Sonora to Jalisco, and around Isla Revillagigedo; (2) the Hawaiian Islands from Kauai to Hawaii; and (3) around the Mariana, Bonin, and Ryukyu Islands and Taiwan (Johnson and Wolman 1984). During July, when the seismic survey is proposed to occur, most eastern North Pacific humpback whales are on their feeding grounds in Alaska, with smaller numbers summering off the USWC, including California, Oregon, and Washington (Calambokidis et al. 2001). Photographic identification studies indicate that a relatively small number of individuals utilize those areas consistently (Calambokidis et al. 2001, 2003). A few of the humpbacks sighted off Oregon during the summer have been calves (Steiger and Calambokidis 2000).

The humpback whale is the most common species of large cetacean reported off the coasts of Oregon/Washington from May to November, with highest numbers reported from May to September; no humpbacks have been observed there in the winter (Green et al. 1992; Calambokidis et al. 2000, 2003). Shifts in seasonal abundance observed off Oregon/Washington suggest north–south movement (Green et al. 1992). Off Oregon/Washington, humpbacks occur primarily over the continental shelf and slope during the summer and fall, with few reported in offshore pelagic waters (Green et al. 1992, Calambokidis et al. 2003). In particular, humpbacks tend to concentrate off Oregon along the southern edge of Heceta Bank, in the Blanco upwelling zone, and other areas associated with upwelling. During extensive systematic aerial surveys conducted up to ~556 km (300 n.mi.) off the Oregon/Washington coast, only one humpback whale was reported in offshore waters >200 m (656 ft) deep. That sighting was located ~70 km (38 n.mi.) west of Cape Blanco during the spring (see Fig. 1; Green et al. 1992). Encounter rates off Oregon/Washington during the summer were highest over the slope (2.16/1000 km^2) followed by shelf waters (0.56), with no sightings in offshore waters during the summer. Those studies indicate that humpbacks may be encountered in the slope waters of the Gorda Ridge contingency survey area, but are very unlikely to be sighted in the deeper offshore waters of the main Blanco survey area. Thus, during the survey in July, humpback whales potentially may be encountered in low numbers near the Gorda Ridge contingency site if that survey indeed occurs.

Humpback whales are often sighted singly or in groups of two or three, although loose feeding aggregations of up to 35 have been sighted over the continental shelf off Oregon/Washington (Green et al. 1992). Calves have also been sighted in continental shelf waters. Sexual maturity is reached at about 5 years (Clapham 2002). Females usually give birth to one calf every 2 years, although annual calving is also known to occur (Clapham and Mayo 1990; Glockner and Ferrari 1990). Gestation lasts ~11 months, and most calves are born during mid-winter (Clapham 2002). Males sing a characteristic song when on the wintering grounds (Winn and Reichley 1985) and occasionally when migrating. Singing is generally thought to be used to attract females and/or establish territories (Payne and McVay 1971; Winn and Winn

1978; Darling et al. 1983; Glockner 1983; Mobley et al. 1988; Clapham 1996). Humpback whales produce sounds in the frequency range 20 Hz–8.2 kHz, although songs have dominant frequencies of 120–4000 Hz (review by Thomson and Richardson 1995). When at high latitudes, including Oregon/Washington, humpbacks typically feed on krill and small schooling fish.

Minke Whale (*Balaenoptera acutorostrata*)

Minke whales have a cosmopolitan distribution that spans ice-free latitudes (Stewart and Leatherwood 1985). In the Pacific, they are usually seen over continental shelves, but they are not considered abundant in the NPO (Brueggeman et al. 1990). Thus, they are not likely to be seen in the offshore deep waters of the study area. In the NPO, minke whales range from the Chukchi Sea in summer to within 2º of the equator in winter (Perrin and Brownell 2002). In the far north, minke whales are thought to be migratory, but they are believed to be resident off the USWC year-round (Dorsey et al. 1983). Barlow (1997) reported an abundance estimate of 631 for California/Oregon/Washington waters based on survey data collected in 1991–1996 for California/Oregon/Washington waters. Barlow (2003) estimated 1015 in that same large area, and 411 and 127 animals just off Oregon/Washington in 1996 and 2001, respectively. Densities ranged from 0.0004 to 0.0013/km^2 off Oregon/Washington, and 0.0003 to 0.0009/km^2 off California (Barlow 2003).

Minke whales seem able to find and exploit small and transient concentrations of prey (including both fish and invertebrates) and the more stable concentrations that attract multi-species assemblages of large predators. Minke whales are relatively solitary but can occur in aggregations of up to 100 animals when food resources are concentrated. Green et al. (1993) and Barlow (2003) report sighting mainly single minkes off Oregon and Washington. Females give birth every year (Sergeant 1963). Gestation lasts ~10 months, and calving typically occurs from November to March (Sergeant 1963).

The small size, inconspicuous blows, and brief surfacing times of minke whales mean that they are easily overlooked in heavy sea states, although they are known to approach vessels in some circumstances (Stewart and Leatherwood 1985). Detection of minke whales with listening devices is unreliable. A large variety of sounds, ranging in frequency from 60 Hz to 12 kHz, has been attributed to minke whales (Stewart and Leatherwood 1985; Edds-Walton 2000; Mellinger et al. 2000; Gedamke et al. 2001).

Sei Whale (*Balaenoptera borealis*)

The sei whale has a cosmopolitan distribution, with a marked preference for temperate oceanic waters (Gambell 1985a). In the open ocean, sei whales generally migrate from temperate zones occupied in winter to higher latitudes in the summer, where most feeding takes place (Gambell 1985a). Sei whale populations were depleted by whaling, and their current status is generally uncertain (Horwood 1987). The sei whale is listed as ***Endangered*** under the ESA.

Sei whales are rare in the waters off California, Oregon, and Washington (Brueggeman et al. 1990; Green et al. 1992; Barlow 1997; Forney et al. 1995). Very few confirmed sightings are known for California (Hill and Barlow 1992; Carretta and Forney 1993; Mangels and Gerrodette 1994; Von Saunder and Barlow 1999; Barlow 2003). Green et al. (1992, 1993) and Barlow (2003) made no sightings off Oregon and Washington. Barlow (2003) estimated the abundance of sei whales in waters off California at 56, based on surveys from 1996 and 2001.

Sei whales are mainly pelagic, and usually occur in small groups of up to six. They feed on copepods, euphausiids, amphipods, squid, and small schooling fish (Leatherwood and Reeves 1983). They tend to make only shallow dives, and surface relatively frequently. They apparently produce sounds in the range of 1.5–3.5 kHz, though few data on their calls are available (review by Thomson and Richardson 1995).

Sei whales show sexual dimorphism, with females being larger than males (Horwood 2002). They become sexually mature at about 10 years of age (Horwood 2002). In northern waters, calving occurs in December, after a gestation period of ~1 year (Horwood 2002).

Fin Whale (*Balaenoptera physalus*)

Fin whales are widely distributed in all the world's oceans (Gambell 1985b), but typically occur in temperate and polar regions. They appear to have complex seasonal movements, and are likely seasonal migrants (Gambell 1985b). Fin whales mate and calve in temperate waters during the winter, but migrate to northern latitudes during the summer to feed (Mackintosh 1965 *in* Gambell 1985b). The North Pacific population summers from the Chukchi Sea to California, and winters from California southwards (Gambell 1985b). The fin whale is listed as ***Endangered*** under the ESA, and it is a CITES Appendix I species (Table 2).

Barlow and Taylor (2001) estimated the population of fin whales off the coasts of California/Oregon/Washington as 1851, based on surveys in 1993 and 1996; Barlow (2003) estimated a population size of 3279 based on survey data collected in 1996 and 2001. Abundance estimates for Oregon and Washington alone were 283 and 380 (Barlow 2003). Aggregations of fin whales are found year-round off southern and central California (Dohl et al. 1983; Forney et al. 1995; Barlow 1997) and in the summer off Oregon (Green et al. 1992). Vocalizations from fin whales have been detected year-round off northern California, Oregon, and Washington (Moore et al. 1998). Barlow (2003) noted densities of up to 0.0012/km^2 off Oregon/Washington and up to 0.004/km^2 in waters off California.

Fin whales occur in coastal, shelf, and oceanic waters. Sergeant (1977) proposed that fin whales tend to follow steep slope contours, either because they detect them readily, or because biological productivity is high along steep contours because of tidal mixing and perhaps current mixing. Fin whales are typically observed alone or in pairs, but on feeding grounds, up to 20 individuals can occur together. They feed on euphausiids, copepods, squid, and small schooling fish. In the Northern Hemisphere, the peak breeding season is December–January (Gambell 1985b).

The diving behavior of fin whales in the western North Atlantic was reviewed by Stone et al. (1992) with the objective of evaluating the likelihood of detection by aerial and shipboard surveys. Fin whales in their study area blew about 50 times/hour, and the average dive time was about 3 min. As fin whales do not usually remain submerged for long periods, have tall blows, have a conspicuous surfacing profile, and often occur in groups of several animals, they are less likely to be overlooked than most other species.

The distinctive 20-Hz pulses of fin whales, with source levels as high as 180 dB re 1 μPa, can be heard reliably to distances of several tens of kilometers (Watkins 1981; Watkins et al. 1987; Edds 1988; Cummings and Thompson 1994) or even further (Cummings and Thompson 1971; Payne and Webb 1971). Watkins (1981) believes that most fin whale responses to singers are at distances <15 km (8 n.mi.). Fin whales primarily emit their 20-Hz signals during their reproductive season from autumn to early spring, and the calls have been recorded in the Gulf of California (Cummings et al. 1986; Thompson et al. 1992; Hayes et al. 1995). Watkins et al. (1987) believed that the repetitive signals are an acoustic display associated with reproduction, and Croll et al. (2002) report that it is the male fin whales that make strong calls. Fin whales also produce sounds at frequencies up to 150 Hz, including 34–75-Hz tones, a 129–150-Hz tone preceding 20-Hz sounds, and generally downsweeping pulses in the range 118–14 Hz (Watkins 1981; Cummings et al. 1986; Edds 1988). Watkins (1981) heard those sounds mostly during interactions of two or more whales, and speculated that the sounds were used to communicate with nearby whales. Fin whales >15–20 km (8–10.8 n.mi.) from one another apparently do not emit the higher-frequency sounds (Watkins 1981).

Blue Whale (*Balaenoptera musculus*)

The blue whale is widely distributed throughout most of the world's oceans, occurring in coastal, shelf, and oceanic waters. The worldwide population has been estimated at 15,000, with 10,000 in the Southern Hemisphere (Gambell 1976), 3500 in the North Pacific, and up to 1400 in the North Atlantic (NMFS 1998). Blue whale calls monitored from the U.S. Navy Sound Surveillance System (SOSUS) and other offshore hydrophones suggest that separate populations occur in the eastern and western North Pacific (Stafford et al. 1999, 2001; Watkins et al. 2000a). Blue whales are considered rare off Oregon and Washington (Buchanan et al. 2001), and are not likely to be seen in the study area. Barlow (2003) estimated an abundance of 1736 in California/Oregon/Washington waters, based on data collected in 1996 and 2001, but only 0–101 animals in the Oregon/Washington part of this area. Calambokidis and Barlow (2004) estimated ~3000 blue whales for California/Oregon/Washington, based on line-transect surveys, and 2000 based on capture-recapture methods. Carretta et al. (2002) noted that the best estimate of abundance off California/Oregon/Washington is an average of line-transect and capture-recapture estimates, and they gave an estimate of 1940. A density estimate of 0.0003/km^2 was given for waters off Oregon/Washington, and densities off California ranged from 0.001 to 0.0033/km^2 (Barlow 2003).

Generally, blue whales are seasonal migrants between high latitudes in the summer, where they feed, and low latitudes in winter, where they mate and give birth (Lockyer and Brown 1981). However, some individuals may stay in low or high latitudes throughout the year (Reilly and Thayer 1990; Watkins et al. 2000b). Little is known about the movements and wintering grounds of the stocks (Mizroch et al. 1984). However, broad-scale acoustic monitoring indicates that blue whales occurring in the northeast Pacific (including the Oregon/Washington area) during summer and fall may winter in the Eastern Tropical Pacific (Stafford et al. 1999, 2001).

The distribution of the species, at least during times of the year when feeding is a major activity, is in areas that provide large seasonal concentrations of euphausiids, which are the whale's main prey (Yochem and Leatherwood 1985). One population feeds in California waters from June to November and migrates south in winter/spring (Calambokidis et al. 1990; Mate et al. 1999). Blue whales also have been heard off Oregon (McDonald et al. 1995; Stafford et al. 1998; Von Saunder and Barlow 1999), but sightings in the area are rare. During summer, blue whale call locations from the Northwest Pacific were closely associated with cold water and sharp sea surface temperature gradients or fronts, parameters corresponding to zooplankton concentrations; from fall through spring, call locations were concentrated primarily near seamounts (Moore et al. 2002).

Blue whales usually occur alone or in small groups (Leatherwood and Reeves 1983; Palacios 1999). Barlow (2003) noted mean group sizes ranging from 1 to 1.9. Blue whales have a tall and conspicuous blow, and may lift their flukes clear of the surface before a deep dive. Dives can last 10–30 min and are usually separated by a series of 10–20 shallow dives. Swimming speed has been estimated as 2–6.5 km/hr while feeding and 5–33 km/hr while traveling (Yochem and Leatherwood 1985). The best-known sounds of blue whales consist of low-frequency "moans" and "long pulses" ranging from 12.5–200 Hz and can have source levels up to 188 dB re 1 μPa (Cummings and Thompson 1971).

All populations of blue whales have been exploited commercially, and many have been severely depleted as a result. The blue whale is listed as ***Endangered*** under the ESA and by IUCN, and is listed in CITES Appendix I (Table 2).

Pinnipeds

Of the five pinniped species that could occur in or near the project area, only the northern fur seal and northern elephant seal are likely to be present. California sea lions, Steller sea lions, and harbor seals typically do not occur as far offshore as the proposed study area. If they were to be encountered in the proposed study area, they would be more likely to be seen in the contingency survey area, which is located closer to shore than the main survey area.

Northern Fur Seal (*Callorhinus ursinus*)

In the NPO, northern fur seals occur from southern California to the Bering Sea. During the breeding season, 74% of the worldwide population inhabit the Pribilof Islands in the southern Bering Sea (Lander and Kajimura 1982). A small percentage of seals breed at San Miguel Island off southern California. Outside of the breeding season, fur seals may haul out at other sites in Alaska, British Columbia, and areas along the USWC (Fiscus 1983). Bonnell et al (1992) noted the presence of northern fur seals year-round off Oregon and Washington, with the greatest numbers occurring in January–May. The highest densities were seen in the Columbia River plume and in deep offshore waters (>2000 m or 6562 ft) off central and southern Oregon (Bonnell et al. 1992). Offshore densities ranged up to 0.402/km^2 in January–May, but only reached up to 0.1/km^2 in June–December (Bonnell et al. 1992).

Adult females and males occur onshore at different although overlapping times during the breeding season. Adults usually come ashore in May–August and may sometimes be present until November, and adult females are found ashore from June to November (Carretta et al. 2002). After reproduction, seals spend the next 7–8 months feeding at sea (Roppel 1984). Adult females and pups from the Pribilof Islands migrate to Oregon and California offshore waters, but adult males only migrate as far south as the Gulf of Alaska (Kajimura 1984). Bonnell et al. (1992) noted that northern fur seals were 5–6 times more abundant in offshore waters than over the shelf or slope. Off Oregon and Washington, densities for shelf, slope, and offshore waters were 0.017, 0.013, and 0.084/km^2, respectively (Bonnell et al. 1992). Although most fur seals may already be breeding at the time of the proposed survey, some individuals could be encountered in the proposed study area. Bonnell et al. (1992) reported that northern fur seals were seen as far out from the coast as 185 km (100 n.mi.; the offshore limit of the survey), and numbers increased with distance from land.

Northern fur seals are solitary when feeding at sea (Reeves et al. 2002). They feed on nearshore and pelagic squid and fish (Reeves et al. 2002). During feeding, they mostly make shallow dives of up to 50 m (165 ft), but dives can reach depths of 250 m or 820 ft (Reeves et al. 2002).

Bonnell et al. (1992) estimated that 1200 fur seals inhabit the Oregon/Washington area in January and 7000 in April. In January, 77% of sightings in that area were off northern Washington; in April, 77% of all sightings were off central and southern Oregon (Bonnell et al. 1992). The population estimate for San Miguel Island, California, is 4336 (Carretta et al. 2002); there are about 1.2 million worldwide (Reeves et al. 2002). Northern fur seals are not listed as endangered or threatened under the ESA or as "depleted" under the MMPA.

California Sea Lion (*Zalophus californianus*)

The California sea lion found from southern Mexico to southwestern Canada is the subspecies *Z. c. californianus* (other subspecies are found on the Galapagos Islands and in Japan, although the latter is likely extinct). The breeding areas of the California sea lion are on islands located in southern California, western Baja California, and the Gulf of California. Off Oregon and Washington, most California sea lions occur in the fall, when migrating males arrive from California (Bonnell et al. 1992). The movements of females and young are not fully understood, but at least some remain close to their rookeries year-round. Bonnell et al. (1992) noted fall counts of 900–1800 California sea lions off Oregon and Washington, with the greatest number at Shell Island off Cape Arago in southern Oregon.

Although encounters with the species are possible in the proposed study area, it is unlikely that California sea lions would be seen that far offshore and at the season of the proposed study (July). California sea lions are coastal animals that often haul out on shore throughout the year. King (1983) noted that sea lions are rarely found more than 16 km (9 n.mi.) offshore. In California and Baja California, births occur on land from mid-May to late June. Females are ready to breed ~3 weeks after giving birth (Odell 1984; Trillmich 1986) and actively solicit mates. Males establish territories that they defend from other males. Pups are able to swim soon after birth, and at 2–3 weeks of age, they form groups with other young pups.

The California sea lion population is growing at an annual rate of 5–6.2%. Recent population estimates range from 204,000 to 214,000 (Boveng 1988a; Lowry et al. 1992; Lowry 1999). Sea lions are killed incidentally in set and drift-gillnet fisheries (Hanan et al. 1993; Barlow et al. 1994; Julian 1997; Julian and Beeson 1998; Cameron and Forney 1999). California sea lions are not listed as endangered or threatened under the ESA or as "depleted" under the MMPA.

Steller Sea Lion (*Eumetopias jubatus*)

Northern or Steller sea lions are found in the North Pacific Ocean and southern Bering Sea (Reeves et al. 2002). In the NPO, they occur from the Aleutian and Pribilof Islands into the Gulf of Alaska and south to central California (Reeves et al. 2002). They are most abundant in the Gulf of Alaska, southeastern Alaska, and British Columbia (Reeves et al. 2002). Steller sea lions typically inhabit coastal waters when feeding and migrating; thus, they are not expected to occur in the proposed study area. However, if they were to be encountered, this would be more likely in the contingency area than in the main survey area. During surveys off the coasts of Oregon and Washington, Bonnell et al. (1992) noted that 89% of sea lions occurred over the shelf at a mean distance of 21 km (11 n.mi.) from the coast, with the farthest sighting ~40 km (22 km) from shore; all sightings occurred near or in waters <200 m (656 ft). Densities between 125ºW and 127ºW ranged from 0 to 0.01/km^2 (Bonnell et al. 1992).

Steller sea lions aggregate on rocky and gravel beaches throughout the year. Small rookeries exist in California, Oregon, and British Columbia, but the main rookeries are located along the coast of the Gulf of Alaska and in the Aleutian Islands (Reeves et al. 1992). The rookeries off southern Oregon are located along the coast at Rogue and Orford reefs near 42º25' and 42º45'N and 124º30'W, respectively (Bonnell et al. 1992), with a breeding population of at least 1700 animals (Brown 1988 *in* Bonnell et al. 1992); these areas are located near Cape Blanco ~475 km (256 n.mi.) southeast of the main survey area and ~175 km (94 n.mi.) east of the contingency survey area (Fig. 1). The California population numbers ~2000 (Bonnell et al. 1983). Approximately 24.8% of the Steller sea lion population of Oregon and Washington is at sea during May–July.

Adult males are found at breeding colonies in May. Females give birth from late May to early July, with the highest pup counts in July (Bigg 1988). Molting occurs from late summer to early winter. Steller sea lions in Alaska feed on Walleye pollock, as well as herring, cod, salmon and cephalopods in other areas (Reeves et al. 2002). They feed predominantly within 30 km (16 n.mi.) of the coastal rookeries (Bonnell et al. 1992).

The overall abundance of Steller sea lions declined from several hundred thousand in the 1970s to ~60,000 to 70,000 by the late 1990s (Reeves et al. 2002). The decline may be attributable to disease, entanglement mortality, and changes in prey availability (Merrick et al. 1987). Long-term shifts in the North Pacific food web associated with commercial whaling may also have been an important factor (Springer et al. 2003). Under the ESA, the eastern population (those east of 144ºW) of Steller sea lions is listed as ***Threatened***, whereas the western population is listed as ***Endangered*** under the ESA.

Harbor Seal (*Phoca vitulina*)

Harbor seals are distributed in the North Atlantic and North Pacific. Two subspecies occur in the Pacific: *P.v. stejnegeri* in the northwest Pacific Ocean and *P.v. richardsi* in the NPO. *P.v. richardsi* occurs in nearshore coastal and estuarine areas ranging from Baja California, Mexico north to the Pribilof Islands in Alaska (Carretta et al. 2002). There are three separate stocks of harbor seals along the USWC: inland waters of Washington, coastal Oregon and Washington, and California (Boveng 1988b). The Oregon/Washington coast stock is estimated to contain 24,732 harbor seals, and the California stock is estimated to contain 30,293 (Carretta et al. 2002).

Harbor seals haul out on rocks, reefs, beaches, and offshore islands along the USWC (Carretta et al. 2002). They are generally found near the coast. Bonnell et al. (1992) noted that most harbor seals off Oregon and Washington were <20 km (11 n.mi.) from shore, with the farthest sighting 92 km (50 n.mi.) from the coast. During surveys off the Oregon and Washington coasts, 88% of at-sea harbor seals occurred over shelf waters <200 m (656 ft) deep, with a few sightings near the 2000 m (6562 ft) contour, and only one sighting over deeper water (Bonnell et al. 1992). At-sea density for harbor seals was $0.0059/km^2$ (Bonnell et al. 1992). In the fall, most harbor seals are at sea; 67.8% of all at-sea sightings were recorded in September and November (Bonnell et al. 1992).

Harbor seals do not make extensive migrations, but do travel 300–500 km (162–270 n.mi.) on occasion to forage (Herder 1986). They display strong site fidelity for haul-out sites (Pitcher and McAllister 1981). Pupping in Oregon and Washington occurs from April to July (Brown 1988).

Northern Elephant Seal (*Mirounga angustirostris*)

Northern elephant seals breed and give birth in California and Baja California, primarily on offshore islands (Stewart et al. 1994), from December to March (Stewart and Huber 1993). Northern elephant seals currently breed on numerous islands, from Cedros off the west coast of Baja California, north to the Farallons near San Francisco. Bonnell et al. (1992) noted a possible breeding colony at Shell Island, off southern Oregon. Females arrive in late December and January and give birth within ~1 week of their arrival. Pups are weaned after just 27 days and are abandoned by their mothers. Females spend only ~34 days on shore. Juvenile elephant seals typically leave the rookeries in April or May and head north, traveling an average of 900–1000 km (486–540 n.mi.). Most elephant seals return to their natal rookeries when they start breeding (Huber et al. 1991).

Adult elephant seals engage in two long northward migrations per year, one following the breeding season, and another following the annual molt (Stewart and DeLong 1995). Between these two foraging periods, they return to land to molt, with females returning earlier than males (March–April vs. July). After the molt, adult elephant seals then return to their northern feeding areas again until the next winter breeding seasons. When not at their breeding rookeries, adult elephant seals feed at sea far from the rookeries. Males may feed as far north as the eastern Aleutian Islands and the Gulf of Alaska, whereas females feed south of 45ºN (Le Boeuf et al. 1993; Stewart and Huber 1993). Elephant seals feed on deep-water fish and squid (Condit and Le Boeuf 1984).

Bonnell et al. (1992) noted that northern elephant seals were distributed equally in shelf, slope, and offshore waters during surveys conducted off Oregon and Washington. Thus, feeding northern elephant seals could be seen in the proposed study area. Bonnell et al. (1992) sighted elephant seals as far as 150 km (81 n.mi.) from shore, in waters > 2000 m (6562 ft) deep, and telemetry data indicate that they range much farther offshore than that (Stewart and DeLong 1995). Off Oregon and Washington, most elephant seals at sea were sighted during June, July, and September (Bonnell et al. 1992). Sightings in June, July, and September were off Washington, whereas sightings recorded from November through May were off southern Oregon (Bonnell et al. 1992).

The U.S. and Mexican populations are estimated at 127,000 (Stewart et al. 1994), with 101,000 estimated in the California stock (Carretta et al. 2002). Northern elephant seals are not listed as endangered or threatened under the ESA or as "depleted" under the MMPA.

V. Type of Incidental Take Authorization Requested

The type of incidental taking authorization that is being requested (i.e., takes by harassment only, takes by harassment, injury and/or death), and the method of incidental taking.

L-DEO requests an IHA pursuant to Section 101 (a) (5) (D) of the MMPA for incidental take by harassment during its planned seismic survey in the NPO off Oregon during July 2004.

The operations outlined in Sections I and II have the potential to take marine mammals by harassment. Sounds will be generated by the airgun arrays used during the survey, by a bathymetric sonar, by a sub-bottom profiler sonar, and by general vessel operations. "Takes" by harassment will potentially result when marine mammals near the activities are exposed to the pulsed sounds generated by the airgun array or sonars. The effects will depend on the species of cetacean or pinniped, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound (see § VII). Disturbance reactions are likely amongst some of the marine mammals in the general vicinity of the tracklines of the source vessel. No take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (see § XI, "Mitigation Measures"). No lethal takes are expected.

VI. Numbers of Marine Mammals That May be Taken

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in [section V], and the number of times such takings by each type of taking are likely to occur.

VII. Anticipated Impact on Species or Stocks

The anticipated impact of the activity upon the species or stock of marine mammal.

The material for Sections VI and VII has been combined and presented in reverse order to minimize duplication between sections.

- First we summarize the potential impacts on marine mammals of airgun operations, as called for in Section VII. A more comprehensive review of the relevant background information appears in Appendix A. That Appendix is little changed from corresponding parts of § VII in related IHA Applications previously submitted to NMFS concerning L-DEO projects in the following areas: northern Gulf of Mexico (2003 and planned 2004 projects), Hess Deep in the Eastern Tropical Pacific, Norway, Mid-Atlantic Ocean, Bermuda, Southeast Caribbean, and southern Gulf of Mexico (Yucatan Peninsula).
- Then we discuss the potential impacts of operations by L-DEO's bathymetric sonar and a sub-bottom profiler.
- Finally, we estimate the numbers of marine mammals that might be affected by the proposed activity off Oregon in the NPO in July 2004. This section includes a description of the rationale for L-DEO's estimates of the potential numbers of harassment "takes" during the planned survey, as called for in Section VI.

(a) Summary of Potential Effects of Airgun Sounds

The effects of sounds from airguns might include one or more of the following: tolerance, masking of natural sounds, behavioral disturbance, and perhaps temporary or permanent hearing impairment (Richardson et al. 1995).

Tolerance

Numerous studies have shown that pulsed sounds from airguns are often readily detectable in the water at distances of many kilometers. For a summary of the characteristics of airgun pulses, see Appendix A (c). Numerous studies have shown that marine mammals at distances more than a few kilometers from operating seismic vessels often show no apparent response—see Appendix A (e). This is often true even in cases when the pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and pinnipeds have been shown to react behaviorally to airgun pulses under some conditions, at other times mammals of all three types have shown no overt reactions. In general, pinnipeds and small odontocetes seem to be more tolerant of exposure to airgun pulses than are baleen whales.

Masking

Masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, although there are very few specific data on this. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds. Masking effects are discussed further in Appendix A (d).

Disturbance Reactions

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. In the terminology of the 1994 amendments to the MMPA, seismic noise could cause "Level B" harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

Based on NMFS (2001, p. 9293), we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Even with this guidance, there are difficulties in defining what marine mammals should be counted as "taken by harassment". For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic (and sonar) pulses. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be significant to the individual let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales.

Baleen Whales.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, as reviewed in Appendix A (e), baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. In the case of the migrating gray and bowhead whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals. They simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km (2.4–7.8 n.mi.) from the source. A substantial proportion of the baleen whales within these distances may show avoidance or other strong disturbance reactions to the airgun array. Subtle behavioral changes sometimes become evident at somewhat lower received levels, and recent studies reviewed in

Appendix A (e) have shown that some species of baleen whales, notably bowheads and humpbacks, at times show strong avoidance at received levels lower than 160–170 dB re 1 μPa rms.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. However, gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration and much ship traffic in that area for decades (Appendix A *in* Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years (Richardson et al. 1987). It is not known whether whales that tolerate exposure to seismic pulses are stressed.

Toothed Whales.—Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales. However, systematic work on sperm whales is underway.

Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of operating seismic vessels. Some dolphins seem to be attracted to the seismic vessel and floats, and some ride the bow wave of the seismic vessel even when the airguns are firing. However, in a number of monitoring studies there have been indications that small toothed whales tend to head away, or to maintain a somewhat greater distance from the vessel, when the airguns are operating than when they are silent (e.g., Goold 1996a; Calambokidis and Osmek 1998; Stone 2003). Similarly, captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). However, the animals tolerated high received levels of sound (pk–pk level >200 dB re 1 μPa) before exhibiting aversive behaviors.

There are no specific data on the behavioral reactions of beaked whales to seismic surveys. However, most beaked whales tend to avoid approaching vessels of other types (e.g., Kasuya 1986; Würsig et al. 1998). There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operations, are ongoing nearby—see Appendix A (g). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown (see "Strandings and Mortality", below).

All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds, and it is to be expected that they would tend to avoid an operating seismic survey vessel. There were some limited early observations suggesting that sperm whales in the Southern Ocean and Gulf of Mexico might be fairly sensitive to airgun sounds from distant seismic surveys. However, more extensive data from recent studies in the North Atlantic suggest that sperm whales in those areas show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (McCall Howard 1999; Madsen et al. 2002; Stone 2003). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico has been done recently (Tyack et al. in press).

Pinnipeds.—Pinnipeds are not likely to show a strong avoidance reaction. Visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior—see Appendix A (e). These studies show that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies.

Additional details on the behavioral reactions (or the lack thereof) by all types of marine mammals to seismic vessels can be found in Appendix A (e).

Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this for marine mammals exposed to airgun pulses. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds ≥180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in defining the safety (=shut down) radii planned seismic survey. However, those criteria were established before there were any data on the minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed in Appendix A (f) and summarized here,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid temporary threshold shift (TTS) let alone permanent auditory injury, at least for delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

Several aspects of the planned monitoring and mitigation measures for this project are designed to detect marine mammals occurring near the airgun array (and multibeam sonar), and to avoid exposing them to sound pulses that might cause hearing impairment (see § XI, MITIGATION MEASURES). In addition, many cetaceans are likely to show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that theoretically might occur in mammals close to a strong sound source include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds. The following subsections discuss the possibility of TTS, permanent threshold shift (PTS), and non-auditory physical effects.

Temporary Threshold Shift (TTS).—TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

For toothed whales exposed to single short pulses, the TTS threshold appears to be, to a first approximation, a function of the energy content of the pulse (Finneran et al. 2002). Given the available data, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 μPa rms (approx. 221–226 dB pk–pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the

TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel.

There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale.

TTS thresholds for pinnipeds exposed to brief pulses (single or multiple) have not been measured. However, prolonged exposures show that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations (Kastak et al. 1999; Ketten et al. 2001; *cf.* Au et al. 2000).

A marine mammal within a radius of ≤100 m (≤328 ft) around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel. As noted above, most cetacean species tend to avoid operating airguns, although not all individuals do so. In addition, ramping up airgun arrays, which is standard operational protocol for L-DEO, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. However, TTS would be more likely in any odontocetes that bow-ride or otherwise linger near the airguns. While bow-riding, odontocetes would be at or above the surface, and thus not exposed to strong sound pulses given the pressure-release effect at the surface. However, bow-riding animals generally dive below the surface intermittently. If they did so while bow-riding near airguns, they would be exposed to strong sound pulses, possibly repeatedly. If some cetaceans did incur TTS through exposure to airgun sounds, this would very likely be a temporary and reversible phenomenon.

NMFS (1995, 2000) concluded that cetaceans and pinnipeds should not be exposed to pulsed underwater noise at received levels exceeding, respectively, 180 and 190 dB re 1 µPa (rms). The predicted 180 and 190 dB distances for the airgun arrays operated by L-DEO are summarized in § I. For operations in deep water, actual 180 and 190 dB distances are probably somewhat less than these calculated distances (Tolstoy et al. 2004). These sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As summarized above, TTS data that are now available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses stronger than 180 dB re 1 µPa rms.

Permanent Threshold Shift (PTS).—When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal. However, given the possibility that mammals close to an airgun array might incur TTS, there has been further speculation about the possibility that some individuals occurring very close to airguns might incur PTS. Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals. PTS might occur at a received sound level 20 dB or more above that inducing mild TTS if the animal were exposed to the strong sound for an extended period, or to a strong sound with very rapid rise time—see Appendix A (f).

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of pinnipeds and perhaps baleen whales may be lower, and thus may extend to a somewhat greater distance. Baleen whales generally avoid the immediate area around operating seismic vessels. Some pinnipeds do not show strong avoidance of operating airguns. The planned monitoring and mitigation measures, including visual monitoring, ramp ups, power downs, and shut downs of the airguns when mammals are seen within the "safety radii", will minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

Non-auditory Physiological Effects.—Non-auditory physiological effects or injuries that might theoretically occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals exposed to sound from airgun arrays, but there have been no direct studies of the potential for airgun pulses to elicit any of these effects. If any such effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods. During the planned project, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at this frequency, the ensuing resonance could cause damage to the animal. A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 (Balcomb and Claridge 2001; NOAA and USN 2001) might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales.

Until recently, it was assumed that diving marine mammals are not subject to the bends or air embolism. However, a short paper concerning beaked whales stranded in the Canary Islands in 2002 suggests that cetaceans might be subject to decompression injury in some situations (Jepson et al. 2003). If so, this might occur if they ascend unusually quickly when exposed to aversive sounds.

In general, little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects. Also, the planned mitigation measures (§ XI), including ramp ups, power downs, and shut downs will reduce the possibility of any such effects.

Strandings and Mortality

Marine mammals close to underwater detonations of high explosives can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995).

Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval exercises and, in one case, an L-DEO seismic survey, has raised the possibility that beaked whales exposed to strong pulsed sounds may be especially susceptible to injury and/or behavioral reactions that can lead to stranding. Appendix A (g) provides additional details.

Seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by airgun arrays are broadband with most of the energy <1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to physical damage and mortality (NOAA and USN 2001; Jepson et al. 2003), even if only indirectly, suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

In Sept. 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the L-DEO vessel *Maurice Ewing* was operating a 20-gun 8490-in^3 array in the general area. The link between this stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002; Yoder 2002). Nonetheless, this plus the incidents involving beaked whale strandings near naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

(b) Possible Effects of Bathymetric Sonar Signals

A multibeam bathymetric sonar (Atlas Hydrosweep DS-2, 15.5-kHz) will be operated from the source vessel during much of the planned study. Details about this equipment were provided in Section I. Sounds from the multibeam sonar are very short pulses, occurring for 1–10 ms once every 1 to 15 s, depending on water depth. Most of the energy in the sound pulses emitted by this multibeam sonar is at high frequencies, centered at 15.5 kHz. The beam is narrow (2.67º) in fore–aft extent, and wide (140º) in the cross-track extent. Each ping consists of five successive transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the five segments, i.e. for 1/5th or at most 2/5th of the 1–10 ms.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than the Atlas Hydrosweep, (2) have a longer pulse duration, and (3) are directed close to horizontally vs. downward for the Hydrosweep. The area of possible influence of the Hydrosweep is much smaller—a narrow band below the source vessel. Marine mammals that encounter the Hydrosweep at close range are unlikely to be subjected to repeated pulses because of the narrow fore–aft width of the beam, and will receive only limited amounts of pulse energy because of the short pulses.

Masking

Marine mammal communications will not be masked appreciably by the multibeam sonar signals given the low duty cycle of the sonar and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Behavioral reactions of free-ranging marine mammals to military and other sonars appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985), increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999), and the previously-mentioned beachings by beaked whales. Also, Navy personnel have described observations of dolphins bow-riding adjacent to bow-mounted mid-frequency sonars during sonar transmissions. However, all of these observations are of limited relevance to the present situation. Pulse durations from these sonars were much longer than those of the L-DEO multibeam sonar, and a given mammal would have received many pulses from the naval sonars. During L-DEO's operations, the individual pulses will be very short, and a given mammal would not receive many of the downward-directed pulses as the vessel passes by.

Captive bottlenose dolphins and a white whale exhibited changes in behavior when exposed to 1 s pulsed sounds at frequencies similar to those that will be emitted by the multibeam sonar used by L-DEO, and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000; Finneran et al. 2002). The relevance of these data to free-ranging odontocetes is uncertain, and in any case the test sounds were quite different in either duration or bandwidth as compared with those from a bathymetric sonar.

We are not aware of any data on the reactions of pinnipeds to sonar sounds at frequencies similar to those of the 15.5 kHz frequency of the *Ewing*'s multibeam sonar. Based on observed pinniped responses to other types of pulsed sounds, and the likely brevity of exposure to the bathymetric sonar sounds, pinniped reactions are expected to be limited to startle or otherwise brief responses of no lasting consequence to the animals.

As noted earlier, NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans or pinnipeds to small numbers of signals from the multibeam bathymetric sonar system would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is concern that mid-frequency sonar sounds can cause serious impacts to marine mammals (see above). However, the multibeam sonar proposed for use by L-DEO is quite different than sonars used for Navy operations. Pulse duration of the multibeam sonar is very short relative to the naval sonars. Also, at any given location, an individual marine mammal would be in the beam of the multibeam sonar for much less time given the generally downward orientation of the beam and its narrow fore-aft beamwidth. (Navy sonars often use near-horizontally-directed sound.) These factors would all reduce the sound energy received from the multibeam sonar rather drastically relative to that from the sonars used by the Navy.

(c) Possible Effects of Sub-bottom Profiler Signals

A sub-bottom profiler will be operated from the source vessel at some times during the planned study. Details about this equipment were provided in § I. Sounds from the sub-bottom profiler are very short pulses, occurring for 1, 2 or 4 ms once every second. Most of the energy in the sound pulses emitted by this sub-bottom profiler is at mid frequencies, centered at 3.5 kHz. The beamwidth is ~30° and is directed downward.

Sound levels have not been measured directly for the sub-bottom profiler used by the *Ewing*, but Burgess and Lawson (2000) measured sounds propagating more or less horizontally from a similar unit with similar source output (205 dB re 1 µPa·m). The 160 and 180 dB re 1 µPa rms radii, in the horizontal direction, were estimated to be, respectively, near 20 m (66 ft) and 8 m (26 ft) from the source, as measured in 13 m or 43 ft water depth. The corresponding distances for an animal in the beam below the transducer would be greater, on the order of 180 m (591 ft) and 18 m (59 ft), assuming spherical spreading.

The sub-bottom profiler on the *Ewing* has a stated maximum source level of 204 dB re 1 µPa·m (see § I). Thus the received level would be expected to decrease to 160 and 180 dB about 160 m (525 ft) and 16 m (52 ft) below the transducer, respectively, again assuming spherical spreading. Corresponding distances in the horizontal plane would be lower, given the directionality of this source (30° beamwidth) and the measurements of Burgess and Lawson (2000).

Masking

Marine mammal communications will not be masked appreciably by the sub-bottom profiler signals given its relatively low power output, the low duty cycle, directionality, and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses

Marine mammal behavioral reactions to other pulsed sound sources are discussed above, and responses to the sub-bottom profiler are likely to be similar to those for other pulsed sources if received at the same levels. However, the pulsed signals from the sub-bottom profiler are much weaker than those from the airgun array and the multibeam sonar. Therefore, behavioral responses are not expected unless marine mammals are very close to the source. NMFS (2001) has concluded that momentary behavioral reactions "do not rise to the level of taking". Thus, brief exposure of cetaceans to small numbers of signals from the sub-bottom profiler would not result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Source levels of the sub-bottom profiler are much lower than those of the airguns and the multibeam sonar, which are discussed above. Sound levels from a sub-bottom profiler similar to the one on the *Ewing* were estimated to decrease to 180 dB re 1 µPa (rms) at 8 m or 26 ft horizontally from the source (Burgess and Lawson 2000), and at ~18 m downward from the source. Furthermore, received levels of pulsed sounds that are necessary to cause temporary or especially permanent hearing impairment in marine mammals appear to be higher than 180 dB (see earlier). Thus, it is unlikely that the sub-bottom profiler produces pulse levels strong enough to cause hearing impairment or other physical injuries even in an animal that is (briefly) in a position near the source.

The sub-bottom profiler is usually operated simultaneously with other higher-power acoustic sources. Many marine mammals will move away in response to the approaching higher-power sources or the vessel itself before the mammals would be close enough for there to be any possibility of effects from the less intense sounds from the sub-bottom profiler. In the case of mammals that do not avoid the approaching vessel and its various sound sources, mitigation measures that would be applied to minimize effects of the higher-power sources (see § XI) would further reduce or eliminate any minor effects of the sub-bottom profiler.

(d) Numbers of Marine Mammals that Might be "Taken by Harassment"

All anticipated takes would be "takes by harassment", involving temporary changes in behavior. The mitigation measures to be applied will minimize the possibility of injurious takes. (However, as noted earlier and in Appendix A, there is no specific information demonstrating that injurious "takes" would occur even in the absence of the planned mitigation measures.) In the sections below we describe methods to estimate "take by harassment" and present estimates of the numbers of marine mammals that might be affected during the proposed seismic study off Oregon. These estimates are based on data concerning marine mammal densities (numbers per unit area) obtained during surveys off Oregon and Washington during 1996 and 2001 by NMFS/Southwest Fisheries Science Center (SWFSC), and estimates of the size of the area where effects could potentially occur.

This section provides two types of estimates: estimates of the number of potential "exposures", and estimates of the number of different individual cetaceans that might potentially be exposed to sound levels ≥160 and/or ≥170 dB re 1 µPa (rms). The ≥170 dB criterion is applied for delphinids only. Estimates of the number of pinnipeds that may be exposed to sound levels ≥160 and ≥170 dB re 1 µPa (rms) are also presented. The distinction between "exposures" and "number of different individuals exposed" is important in this project, because the plan calls for repeated airgun operations through the same or adjacent waters, primarily at the main Blanco survey site. If many marine mammals are present near any of these lines, then many of the same individuals are likely to be approached by the operating airguns on more than one occasion. In addition, any animals that react to distant seismic sounds by moving away from the source are not likely to be present and affected during the second and subsequent surveys of any given line. This distinction between the number of *exposures* and the number of *different individuals exposed* has been recognized in estimating numbers of "takes" during some previous seismic surveys conducted under IHAs (e.g., Harris et al. 2001; Moulton and Law-son 2002; Smultea and Holst 2003; MacLean and Haley 2004). Estimates of the number of exposures are considered precautionary *overestimates* of the actual numbers of different individuals potentially exposed to seismic sounds, because in all likelihood, exposures represent repeated exposures of some of the same individuals as discussed in the sections that follow.

The following estimates are based on a consideration of the number of marine mammals that might be disturbed appreciably by operations primarily with the 10-airgun array (1300 line km of surveys) and to a lesser extent the 12-airgun array (150 line km) planned to be used during the main Blanco Transform survey plus the Gorda Ridge contingency survey (if done). Only the 10-airgun array would be used during the contingency survey. The anticipated radii of influence of the sonar and sub-bottom profiler are less than those for the airgun arrays. It is assumed that, during simultaneous operations of the multibeam sonar and airguns, any marine mammals close enough to be affected by the sonar would already be affected by the airguns. No animals are expected to exhibit more than short-term and inconsequential responses to these sources given their characteristics (e.g., narrow downward-directed beam) and the planned mitigation measures (§ XI). Such reactions are not considered to constitute "taking" (NMFS 2001). Therefore, no additional allowance is included for animals that might be affected by the multibeam sonar. Any effects of the multibeam sonar during times when it is operating but the airguns are silent are not considered.

Basis for Estimating "Take by Harassment" for 2004 Oregon Study

Extensive systematic aircraft- and ship-based surveys have been conducted for marine mammals offshore of Oregon and Washington (e.g., Bonnell et al. 1992; Green et al. 1992, 1993; Barlow 1997, 2003; Barlow and Taylor 2001; Calambokidis and Barlow 2004). The most comprehensive and recent density data available for cetacean species off slope and offshore waters of Oregon are from the 1996/2001 NMFS/SWFSC "ORCAWALE" ship surveys as synthesized by Barlow (2003). These surveys were conducted up to ~556 km (300 n.mi.) offshore of Oregon and Washington and encompassed L-DEO's two proposed seismic survey sites.

Systematic, offshore at-sea survey data for pinnipeds are more limited. The most comprehensive such studies are reported by Bonnell et al. (1992) and Green et al. (1993) based on systematic aerial surveys conducted in 1989-90 and 1992 primarily from coastal to slope waters with some offshore effort as well. However, oceanographic conditions, including occasional El Niño and La Niña events, influence the distribution and numbers of marine mammals present in the NPO, including Oregon, resulting in considerable year-to-year variation in the distribution and abundance of many marine mammal species (Forney and Barlow 1998; Buchanan et al. 2001; Escorza-Treviño 2002; Ferrero et al. 2002; Philbrick et al. 2003). Thus, for some species the densities derived from recent surveys may not be representative of the densities that will be encountered during the proposed seismic survey.

Table 3 gives the average and maximum densities for each species or species group of marine mammals reported off Oregon and Washington, corrected for effort, based on the densities reported for the 1996/2001 ORCAWALE surveys (Barlow 2003). The densities from these studies had been corrected, by the original author, for both detectability bias and availability bias. Detectability bias is associated with diminishing sightability with increasing lateral distance from the trackline [*f*(0)]. Availability bias refers to the fact that there is less-than-100% probability of sighting an animal that is present along the survey trackline, and it is measured by *g*(0).

It should be noted that the following estimates of "takes by harassment" assume that both the main Blanco Transform survey and the Gorda Ridge contingency survey will be undertaken and completed. However, it is highly unlikely that there will be sufficient time to complete both surveys or even to start the Gorda Ridge contingency survey. As is typical on offshore ship surveys, inclement weather and equipment malfunctions are likely to cause delays and may limit the number of useful line-kilometers of seismic operations that can be undertaken. Furthermore, any marine mammal sightings within or near the designated safety zones will result in the shut down or power down of seismic operations as a mitigation measure. Thus, the following estimates of the numbers of marine mammals potentially exposed to 160 or 170 dB sounds are precautionary, and probably overestimate the actual numbers of marine mammals that might be involved. These estimates assume that there are no weather, equipment, or mitigation delays, which is highly unlikely, particularly given the usual inclement weather conditions that occur off Oregon during the summer months and the complexity of the equipment involved.

There is some uncertainty about the representativeness of the data and the assumptions used below to estimate the potential "take by harassment". Also, to provide some allowance for these uncertainties "best estimates" as well as "maximum estimates" of the numbers potentially affected have been derived. Best and maximum estimates are based on the average and maximum estimates of densities reported by Barlow (2003) described above. The estimated number of potential exposures and individuals exposed are presented separately below based on the 160 dB (all cetaceans and pinnipeds) and 170 dB (delphinids and pinnipeds only) re 1 μPa (rms) zones where marine mammals might change their behavior in response to acoustic stimuli from seismic operations.

TABLE 3. Densities of marine mammals sighted during surveys off Oregon and Washington, with their approximate coefficients of variation (CV). Cetacean densities are from Barlow (2003) and are based on ship transect surveys conducted up to 300 n.mi. (~550 km) offshore in 1996 and/or 2001. Pinniped densities are from at-sea surveys conducted by Bonnell et al. (1992) and Green et al. (1993). Densities are corrected for *f*(0) and *g*(0). Species listed as "endangered" under the ESA are in italics.

Species	Average Density (#/km^2)		Maximum Density (#/km^2)	
	Density	CV [a]	Density	CV
Odontocetes				
Sperm whale	*0.0009*	*0.65*	*0.0014*	*0.72*
Pygmy sperm whale	0.0006	0.94	0.0015	0.94
Dwarf sperm whale	0.0000	-1.00	0.0000	-1.00
Cuvier's beaked whale	0.0000	-1.00	0.0000	-1.00
Baird's beaked whale	0.0003	0.68	0.0004	0.83
Blainville's beaked whale	0.0000	-1.00	0.0000	-1.00
Hubb's beaked whale	0.0000	-1.00	0.0000	-1.00
Stejneger's beaked whale	0.0000	-1.00	0.0000	-1.00
Mesoplodon sp. (unidentified)	0.0026	0.83	0.0067	0.83
Bottlenose dolphin	0.0000	-1.00	0.0000	-1.00
Striped dolphin	0.0001	0.94	0.0002	0.94
Short-beaked common dolphin	0.0118	0.83	0.0194	0.94
Pacific white-sided dolphin	0.0296	0.55	0.0336	0.62
Northern right-whale dolphin	0.0222	0.50	0.0314	0.57
Risso's dolphin	0.0223	0.48	0.0252	0.58
False killer whale	0.0000	-1.00	0.0000	-1.00
Killer whale	0.0023	0.62	0.0036	0.72
Short-finned pilot whale	0.0000	-1.00	0.0000	-1.00
Phocoenidae				
Dall's porpoise	0.1059	0.28	0.2365	0.31
Mysticetes				
North Pacific right whale	*0.0000*	-1.00	*0.0000*	-1.00
Humpback whale	*0.0005*	0.58	*0.0011*	0.60
Minke whale	0.0007	0.76	0.0013	0.83
Sei whale	*0.0000*	*-1.00*	*0.0000*	*-1.00*
Fin whale	*0.0010*	*0.46*	*0.0012*	*0.57*
Blue whale	*0.0001*	0.76	*0.0003*	0.76
Pinnipeds[b]				
Northern fur seal	0.0151	N.A.	N.A.	N.A.
Northern elephant seal	0.0028	0.54	N.A.	N.A.

N.A. = data not available.

[a]CV (Coefficient of Variation) is a measure of a number's variability. The larger the CV, the higher the variability. It is estimated by the equation $0.94 - 0.162\log_e n$ from Koski et al. (1998), but likely underestimates the true variability.

[b] The numbers of at-sea sightings of California sea lions, Steller sea lions, listed as "threatened" under the ESA, and harbor seals were too small to provide meaningful density estimates (Bonnell et al. 1992; Green et al. 1993). Furthermore, those three pinniped species are not expected to occur in the project area (see text).

Potential Number of "Takes by Harassment" Based on "Exposures"

Best and Maximum Estimates of "Exposures" to ≥160 dB

The potential number of *occasions* when members of each species might be exposed to received levels ≥160 dB re 1 μPa (rms) was calculated by multiplying

- the species' expected density, either "average" (i.e., best) or "maximum", corrected as described above, times
- the anticipated total line-kilometers of operations with the 10- and 12-airgun arrays (including turns and additional buffer line km to allow for repeating of lines due to equipment malfunction, bad weather, etc.), times
- the cross-track distances within which received sound levels are predicted to be ≥160 dB.

For each airgun configuration, that cross track distance is 2x the predicted 160 dB radius, ranging from 2 x 6.50 km for the 10-airgun array to 2 x 7.25 km for the 12-airgun array.

Based on this method, the "best" and "maximum" estimates of the number of marine mammal exposures to airgun sounds ≥160 dB re 1 μPa (rms) was obtained using the reported average and maximum densities from Table 3. These estimates show that four endangered cetacean species may be exposed to such noise levels. Our respective best and maximum estimates for these species are as follows: sperm whale, 17 and 27 exposures; humpback whale, 9 and 21 exposures; fin whale, 20 and 23 exposures; and blue whale, 2 and 6 exposures. Most of the best and maximum exposures to seismic sounds ≥160 dB would involve delphinids (40%) or phocinids (48%, all Dall's porpoises). Best and maximum estimates of the number of exposures of cetaceans, in descending order, are Dall's porpoise (2021 and 4511 exposures), Pacific white-sided dolphin (564 and 641), Risso's dolphin (425 and 481), and northern right whale dolphin (423 and 599). Estimates for other species are lower (Table 4).

The far right column in Table 4, "*Requested Take Authorization*", shows ***the numbers for which "take authorization" is requested***. For the common species, these requested take authorization numbers are calculated as indicated above based on the *maximum* densities reported by Barlow (2003) during either the 1996 or 2001 surveys for cetaceans off Oregon and Washington. In some cases, the requested numbers are somewhat higher than the maximum estimated numbers of exposures found in column 2 of Table 4. Some of the marine mammal species that are known or suspected to occur at least occasionally in slope or offshore waters off Oregon were not recorded during the ORCAWALE surveys (Barlow 2003), or were recorded in very low numbers. The *Requested Take Authorization* figure includes an adjustment for small numbers of balaenopterids and other species that might be encountered even though they were not recorded during the ORCAWALE surveys. It also includes adjustment for potentially increased numbers (5–50) of certain species that were observed infrequently or not at all during ORCAWALE but that might be encountered in relatively large groups during the proposed activity. For these species, the mean observed group size during ORCAWALE surveys or other surveys (Green et al. 1992, 1993) was generally used to derive numbers for the "*Requested Take Authorization*" column.

The best and maximum estimates are based on 160 dB distances predicted from the acoustic model applied by L-DEO (see Table 1). Based on the empirical calibration data collected in the Gulf of Mexico in 2003 for L-DEO's 10- and 12-airgun arrays in deep water (3200 m or 10,500 ft), actual 160 dB distances in deep water are likely to be less than predicted (Tolstoy et al. 2004). Given these considerations, the predicted numbers of marine mammals that might be exposed to sounds ≥160 dB may be somewhat overestimated.

TABLE 4. Estimates of the possible numbers of marine mammal exposures to different sound levels, and the numbers of different individuals that might be exposed, during L-DEO's proposed main Blanco Transform seismic survey and the Gorda Ridge contingency survey (combined) off Oregon in July 2004. The proposed sound sources include 10- and 12-airgun arrays with total volumes of 3050 and 3725 in^3, respectively. Received levels of airgun sounds are expressed in dB re 1 µPa (rms, averaged over pulse duration). Not all marine mammals will change their behavior when exposed to these sound levels, but some may alter their behavior when levels are lower (see text). Delphinids and pinnipeds are unlikely to react to levels below 170 dB. Species in italics are listed under the ESA as endangered (the Steller sea lion is listed as threatened). The column of numbers in boldface shows the numbers of "takes" for which authorization is requested.[a]

	Number of Exposures to Sound Levels ≥160 dB (≥170 dB, Delphinids/Pinnipeds Only)				Number of Individuals Exposed to Sound Levels ≥160 dB (≥170 dB, Delphinids/Pinnipeds Only)					
					Best Estimate					
Species	**Best Estimate**		**Maximum Estimate**		**Number**		**% of Regional Pop'n[b]**	**Maximum Estimate**		**Requested Take Authorization**
Physeteridae										
Sperm whale	*17*		*27*		*5*		*0.0*	*7*		***27***
Pygmy sperm whale	11		29		3		*0.1*	8		**29**
Dwarf sperm whale	0		0		0		NA	0		**5**
Ziphiidae										
Cuvier's beaked whale	0		0		0		0.0	0		**2**
Baird's beaked whale	5		8		1		0.0	2		**8**
Blainville's beaked whale							NA			**20**
Hubb's beaked whale							NA			**54**
Stejneger's beaked whale							NA			**54**
Mesoplodon sp. (unidentified)	49		128		13		0.1	35		
Delphinidae										
Bottlenose dolphin	0	0	0	0	0	0	0.0	0	0	**10**
Striped dolphin	2	(1)	4	(1)	1	0	0.0	1	0	**10**
Short-beaked common dolphin	225	(69)	370	(114)	61	(25)	0.0	101	(40)	**370**
Pacific white-sided dolphin	564	(173)	641	(197)	154	(62)	0.3	175	(70)	**641**
Northern right-whale dolphin	423	(130)	599	(184)	115	(46)	0.6	163	(65)	**599**
Risso's dolphin	425	(130)	481	(148)	116	(46)	0.7	131	(52)	**481**
False killer whale	0	0	0	0	0	0	0.0	0	0	**10**
Killer whale	43	(13)	69	(21)	12	(5)	0.1	19	(7)	**69**
Short-finned pilot whale	0	0	0	0	0	0	0.0	0	0	**50**
Phocoenidae										
Harbor porpoise	0		0		0		0.0	0		**5**
Dall's porpoise	2021		4511		551		0.5	1230		**4511**
Balaenopteridae										
North Pacific right whale	*0*		*0*		0		*0.0*	*0*		***2***
Humpback whale	*9*		*21*		*2*		*0.0*	*6*		***21***
Minke whale	14		25		4		*0.0*	7		**25**
Sei whale	*0*		*0*		0		*0.0*	*0*		***2***
Fin whale	*20*		*23*		5		*0.1*	*6*		***23***
Blue whale	*2*		*6*		1		*0.0*	*2*		***6***

TABLE 4. continued

Pinnipeds						
Northern fur seal	288 (88)	1833 (563)	79 (31)	*0.0*	500 (200)	**1833**
California sea lion						**5**
Steller sea lion						***10***
Harbor seal						**5**
Northern elephant seal	53 (16)	53 (16)	15 (6)	*0.0*	15 (6)	**53**

[a] Best estimate and maximum estimates of density are from Table 3.
[b] Regional population size estimates are from Table 2.
[c] NA indicates that regional population estimates are not available.

Best and Maximum Estimates of Delphinid Exposures to ≥170 dB

The 160-dB criterion, on which the preceding estimates are based, was derived from studies of baleen whales. Odontocete hearing at low frequencies is relatively insensitive and delphinids generally appear to be more tolerant of strong low-frequency sounds than are most baleen whales. As summarized in Appendix A(e), delphinids commonly occur within distances where received levels would be expected to exceed 160 dB (rms). There is no generally accepted alternative "take" criterion for dolphins exposed to airgun sounds. However, our estimates assume that only those dolphins exposed to ≥170 dB re 1 μPa (rms), on average, would be affected sufficiently to be considered "taken by harassment". ("On average" means that some individuals might react significantly upon exposure to levels somewhat less than 170 dB, but others would not do so even upon exposure to levels somewhat exceeding 170 dB.) As such, the best and maximum estimates of the numbers of exposures to ≥170 dB for the four most common delphinid species would be as follows: Pacific white-sided dolphin, 173 and 197; northern right whale dolphin, 130 and 184; Risso's dolphin, 130 and 148; and short-beaked common dolphin, 69 and 114. Estimates for other species are lower (Table 4). These values are based on the predicted 170 dB radii around each of the two array types (Table 1) and are considered to be *more realistic estimates* of the numbers of occasions when delphinids may be affected. However, actual 170 dB radii are probably somewhat less than those estimated from L-DEO's model (Tolstoy et al. 2004), so these estimated numbers of exposures to ≥170 dB may be overestimates.

As described above, the final column on the right in Table 4 ("*Requested Take Authorization*") shows the estimated maximum number of delphinid exposures, by species, with upward adjustments comparable to those applied in the ≥160 dB column, for species sighted infrequently or not at all during the Barlow (2003) surveys.

Estimates of Pinniped Exposures

Only two of the five pinniped species likely occur in the offshore and slope waters (where the project is to occur) in numbers greater than a few stray individuals, based on results of extensive aerial surveys conducted from the coast to offshore waters of Oregon and Washington (Bonnell et al. 1992; Green et al. 1993; Buchanan et al. 2001; Carretta et al. 2002). These are: the northern fur seal and the northern elephant seal. Pinniped sightings recorded at sea over slope and offshore waters were sufficient to produce useful density estimates for those two species (Bonnell et al. 1992; Green et al. 1993). The density estimates were corrected by the original authors for $f(0)$, and we corrected them for $g(0)$, using values from Koski et al. (1998). However, the resulting densities are probably not representative. They probably overestimate the densities expected to occur near the survey sites, as the data were collected during different seasons/months than the proposed July project, and/or were averaged over coastal, shelf, slope, and offshore waters. These factors strongly influence the densities of these pinnipeds at sea, as all pinnipeds off Oregon and Washington exhibit seasonal and/or inshore–offshore movements largely related to breeding and feeding (Bonnell et al. 1992; Buchanan et al. 2001; Carretta et al. 2002). No at-sea density estimates were available for slope and offshore waters in the cases of the other three species of pinnipeds known to occur regularly off Oregon and Washington: the California sea lion, Steller sea lion, and harbor seal. Those three species are relatively infrequent in offshore waters.

The radii around the array where the received level would be ≥160 dB re 1 μPa (rms), the level at which some pinnipeds might alter their behavior when exposed to airgun sounds, have been estimated as 6500 and 7250 m, respectively, for the 10- and 12-airgun arrays (Table 1). Also, as summarized in Appendix A, some studies suggest that pinnipeds, like delphinids, may be less sensitive to airgun sounds than mysticetes. Thus, the numbers of pinnipeds likely to be exposed to received levels ≥170 dB re 1 μPa (rms) were also calculated, based on the estimated 170 dB radii of 2000 and 2200 m for the 10- and 12-airgun arrays, respectively (Table 1). For operations in deep water, these estimated 160 and 170 dB radii are very likely overestimates of the actual 160 and 170 dB distances (Tolstoy et al. 2004). Thus, the resulting estimates of the numbers of pinnipeds exposed to such levels may be overestimated.

The methods described previously for cetaceans were also used to calculate exposure numbers for pinnipeds. However, only one density estimate per species, considered the "best estimate" herewith, was available to estimate the number of exposures of northern fur seals and northern elephant seals during L-DEO's proposed seismic survey. Using these "best" densities, 288 exposures of northern fur seals and 53 exposures of northern elephant seals to airgun sounds ≥160 dB re 1 μPa (rms) may occur during the proposed Blanco Transform/Gorda Ridge seismic surveys. Based on the 170 dB criterion, 88 northern fur seal and 16 northern elephant seal exposures may occur (Table 4). The remaining three pinniped species (California sea lion, Steller sea lion, and harbor seal) are expected to occur in the project areas only in small numbers, if at all, and estimates of the maximum numbers that may be exposed are shown in Table 4 in the final right column, "*Requested Take Authorization*". A maximum of five California sea lion exposures, 10 threatened Steller sea lion exposures, and five harbor seal exposures might occur.

Potential Number of Different Individuals That Might be Exposed to ≥160 and ≥170 dB

The preceding text estimates the number of occasions when marine mammals of various species might be *exposed* to airgun sounds with received levels ≥160 or ≥170 dB re 1 μPa (rms), whereas the following estimates the number of different *individuals* that might potentially be subjected to such received levels on one or more occasions. As noted earlier, the distinction is important in this project, because there will be many closely spaced passes along survey lines at the main Blanco project site (0.5, 1, 2 or 7.5 km apart, Fig. 2). At the Gorda Ridge contingency site, survey lines will be spaced 12 km apart and will involve only the 10-airgun array; thus, only the 160 dB isopleths (6.5 km for the 10-airgun array) would overlap slightly (Fig. 3). As a result of closely spaced survey lines, primarily at the Blanco Transform site, many of the same individual mammals are likely to be approached by the operating airguns on more than one occasion, and to come within the 160 dB distance, and perhaps the smaller 170 dB distance, more than once. This means that many of the mammals in the project area may be disturbed more than once, or that they may move away from the sound source during the first pass by the vessel and subsequently would not be approached during later passes. Thus, the total number of individuals likely to be disturbed one or more times is *considerably lower* than that calculated above based on the number of exposures.

The number of *different individuals* likely to be exposed to airgun sounds with received levels ≥160 or 170 dB re 1 μPa (rms) on one or more occasions can be estimated by considering the total marine area that would be within the 160 or 170 dB radii around the operating airguns on at least one occasion. This was determined by entering the planned survey lines into a MapInfo Geographic Information System (GIS), using the GIS to identify the relevant areas by "drawing" the applicable 160 or 170 dB buffer around each seismic line (depending on the number of airguns to be used), and then calculating the total area within the buffers. For each species, this area was multiplied by the marine mammal density, thus estimating the minimum number of marine mammals that would be exposed to ≥160 or ≥170 dB on one or more occasions. These estimates are presented in Table 4 as the "*Number of Individuals Exposed to Sound Levels ≥160 dB (≥170 dB, Delphinids/Pinnipeds Only)"*. As discussed earlier, this adjustment applies mainly to the main Blanco survey site.

Applying the approach described above, ~5200 km^2 would be within the 160 dB isopleth zones at the main and contingency sites on one or more occasions; in comparison, ~19,075 km^2 would be within those zones based on multiplying the total length of the seismic survey lines and the width of the zone exposed to ≥160 dB (two times the 160 dB radius). After adjustment for overlap, the affected area is ~27% of the originally-calculated area (5200 / 19,075 × 100%). This percentage was used to calculate the estimates of the total number of different *individuals* likely to be exposed to sounds ≥160 or ≥170 dB, by multiplying the estimates of *exposures* by 0.27.

This approach does not allow for turnover in the mammal populations in the study areas during the course of the study, and thus it might somewhat underestimate actual numbers of individuals exposed to ≥160 and ≥170 dB. However, during this project, operations at each site will be relatively brief (no more than a few days). Also, any tendency for underestimation that might occur is at least partly offset by the likely overestimation of 160 and 170 dB radii.

Estimated Number of Individuals Exposed to ≥160 dB

Estimates of the number of different individuals of each species that might be exposed to ≥160 dB, adjusted for this overlap, are provided in Table 4 based on the reported average and maximum densities. As an example of how the 27% ratio figure was applied, the estimates of the number of different individual endangered sperm whales that might be exposed to ≥160 dB would be 5 to 7 (17 or 27 × 0.27; Table 4). Estimates of individuals for the other endangered marine mammals that might be exposed to these sound levels are 2–6 humpback whales, 5–6 fin whales, and 1–2 blue whales. For the most common cetacean species, the corresponding estimated numbers of individuals exposed to ≥160 dB are 551–1230 Dall's porpoises, 154–175 Pacific white-sided dolphins, 116–131 Risso's dolphins, and 115–163 northern right whale dolphins.

Estimated Numbers of Delphinids Exposed to ≥170 dB

Applying the method described above to the common delphinids, the estimated numbers of individuals exposed to airgun sounds with levels ≥170 dB are 62–70 Pacific white-sided dolphins, 46–65 northern right whale dolphins, 46–52 Risso's dolphins, and 25–40 short-beaked common dolphins (Table 4). These values are based on the predicted 170 dB radii around the 10- and 12-airgun arrays proposed to be used at both the main Blanco Transform site and Gorda Ridge contingency site. These are believed to be more realistic estimates of the numbers of delphinids that might be affected by the proposed activities.

Estimates of Individual Pinnipeds Exposed

The estimated numbers of individual northern fur seals and northern elephant seals that might be exposed to sounds ≥160 dB and ≥170 dB re 1 μPa (rms) can be calculated in the same way. The resulting estimates are 79 and 15 fur seals, and 31 and 6 elephant seals, respectively. For other pinniped species, our best estimate of the number of individuals that might be exposed to such levels is zero in each case.

Conclusions

The main Blanco Transform survey and the Gorda Ridge contingency survey will involve towing an airgun array that introduces pulsed sounds into the ocean, along with simultaneous operation of a multibeam sonar and sub-bottom profiler. Bottom-mounted seismometers, along with a towed hydrophone streamer, will be deployed to receive and record these returning signals. Most (≤1300 km) of the seismic survey will be conducted with a 10-airgun array with total air volume 3050 in^3; the remainder (~150 km) of the survey will employ a 12-airgun array with total air volume 3705 in^3. Routine vessel operations, other than the proposed airgun operations, are conventionally assumed not to affect marine mammals sufficiently to constitute "taking". No "taking" of marine mammals is expected in association with operations of the bathymetric sonar, because the sonar sounds are beamed downward, the beam is narrow, the pulses are extremely short, etc.

Cetaceans

Strong avoidance reactions by several species of mysticetes to seismic vessels have been observed at ranges up to 6–8 km (3.2–4.3 n.mi.) and occasionally as far as 20–30 km (10.8–16.2 n.mi.) from the source vessel. However, reactions at the longer distances appear to be atypical of most species and situations. Furthermore, if they are encountered, the numbers of mysticetes estimated to occur within the 160 dB isopleth at the Blanco Transform and Gorda Ridge survey sites are expected to be low. In addition, the estimated numbers presented in Table 4 are considered overestimates of actual numbers for two primary reasons. First, the number of line kilometers used to estimate the number of exposures and individuals exposed assumes that both the main and contingency surveys will be completed; this is highly unlikely given the likelihood that some inclement weather, equipment malfunction, and/or implementation of mitigative shut downs or power downs will occur. Secondly, the estimated 160 and 170 dB radii used here are probably overestimates of the actual 160 and 170 dB radii at deep water sites such as the Blanco Transform and Gorda Ridge sites (Tolstoy et al. 2004).

Odontocete reactions to seismic pulses, or at least the reactions of dolphins, are expected to extend to lesser distances than are those of mysticetes. Odontocete low-frequency hearing is less sensitive than that of mysticetes, and dolphins are often seen from seismic vessels. In fact, there are documented instances of dolphins approaching active seismic vessels. However, dolphins as well as some other types of odontocetes sometimes show avoidance responses and/or other changes in behavior when near operating seismic vessels.

Taking into account the mitigation measures that are planned, effects on cetaceans are generally expected to be limited to avoidance of the area around the seismic operation and short-term changes in behavior, falling within the MMPA definition of "Level B harassment". Furthermore, the estimated numbers of animals potentially exposed to sound levels sufficient to cause appreciable disturbance are very low percentages of the population sizes in the NPO generally, as described below.

Based on the 160 dB criterion, the *best estimates* of the numbers of *individual* cetaceans that may be exposed to sounds ≥160 dB re 1 μPa (rms) represent 0 to 0.7% of the populations of each species in the NPO (Table 3). The assumed population sizes used to calculate these percentages are presented in Table

2. For species listed as Endangered under the ESA, this includes no North Pacific right whales or Sei whales; ≤0.02% of the NPO populations of sperm, humpback and blue whales; and 0.1% of the fin whale population (Table 4). In the cases of mysticetes, beaked whales, and sperm whales, these potential reactions are expected to involve no more than very small numbers (0 to 7) of individual cetaceans. Sperm and fin whales are the Endangered species that are most likely to be exposed and their NPO populations are ~26,053 and 8520, respectively (Ohsumi and Wada 1974; Carretta et al. 2002).

It is highly unlikely that any right whales will be exposed to seismic sounds ≥160 dB re 1 μPa (rms). This conclusion is based on the rarity of this species off Oregon/Washington and in the NPO generally (<100, Carretta et al. 2002, Table 2), and on the fact that the remnant population of this species apparently migrates to more northerly areas for the summer. However, we request authorization to expose up to two North Pacific right whales to ≥160 dB, given the possibility (however unlikely) of encountering one or more of this endangered species. If a right whale is sighted by the vessel-based observers, the airguns will be shut down (not just powered down) regardless of the distance of the whale from the airgun array.

Larger numbers of delphinids may be affected by the proposed main and contingency seismic studies, but the population sizes of species likely to occur in the operating area are large, and the numbers potentially affected are small relative to the population sizes (Tables 2 and 4). The best estimate of number of *individual* delphinids that might be exposed to sounds ≥170 dB re 1 μPa (rms) represents <0.01% of the ~600,000 dolphins estimated to occur in the NPO, and 0 to 0.7% of the populations of each species occurring there (Tables 2 and 4).

Varying estimates of the numbers of marine mammals that might be exposed to airgun sounds during the July 2004 seismic surveys off Oregon have been presented, depending on the specific exposure criteria (≥160 vs. ≥170 dB), calculation procedures (exposures vs. individuals), and density criteria used (best vs. maximum). The requested "take authorization" for each species is based on the estimated *maximum number of exposures* to ≥160 dB re 1 μPa (rms). That figure *likely overestimates* (in most cases by a large margin) the actual number of animals that will be exposed to these sounds; the reasons for this are outlined above. Even so, the combined estimates for the main and contingency surveys are quite low percentages of the population sizes. Also, these relatively short-term exposures are unlikely to result in any long-term negative consequences for the individuals or their populations.

The many cases of apparent tolerance by cetaceans of seismic exploration, vessel traffic, and some other human activities show that co-existence is possible. Mitigation measures such as controlled speed, course alternation, look outs, non-pursuit, ramp ups, and power downs or shut downs when marine mammals are seen within defined ranges should further reduce short-term reactions, and minimize any effects on hearing sensitivity. In all cases, the effects are expected to be short-term, with no lasting biological consequence.

Pinnipeds

Two pinniped species, the northern fur seal and the northern elephant seal, are likely to be encountered at the survey sites, as they are associated with pelagic slope and offshore waters off Oregon. In addition, it is possible (although unlikely) that a small number of Steller sea lions, California sea lions, and/or harbor seals may also be encountered, most likely at the Gorda Ridge survey area located closer to shore in continental slope water; these three species tend to inhabit primarily coastal and shelf waters. An estimated 79 individual fur seals and 15 individual elephant seals may be exposed to airgun sounds with received levels ≥160 dB re 1 μPa (rms). It is most likely that no California sea lions, Steller sea lions, or harbor seals will be exposed to such sounds. As for cetaceans, the estimated numbers of pinnipeds that may be exposed to received levels ≥160 dB are probably overestimates of the actual numbers that will be affected significantly.

VIII. ANTICIPATED IMPACT ON SUBSISTENCE

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

There is no subsistence hunting for marine mammals in the waters off Oregon in the NPO, so the proposed activities will not have any impact on the availability of the species or stocks for subsistence users.

IX. ANTICIPATED IMPACT ON HABITAT

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

The proposed seismic survey will not result in any permanent impact on habitats used by marine mammals, or to the food sources they utilize. The main impact issue associated with the proposed activity will be temporarily elevated noise levels and the associated direct effects on marine mammals, as discussed in Sections VI/VII, above.

The actual area contacted temporarily by the OBSs will be an insignificant and very small fraction of the marine mammal habitat and the habitat of their food species in the area. The use of OBSs would result in no more than a negligible and highly localized short-term disturbance to sediments and benthic organisms. The area that might be disturbed is a very small fraction of the overall area.

One of the reasons for the adoption of airguns as the standard energy source for marine seismic surveys was that they (unlike the explosives used in the distant past) do not result in any appreciable fish kill. Various experimental studies showed that airgun discharges cause little or no fish kill, and that any injurious effects were generally limited to the water within a meter or so of an airgun. However, it has recently been found that injurious effects on captive fish, especially on fish hearing, may occur to somewhat greater distances than previously thought (McCauley et al. 2000a,b, 2002; 2003). Even so, any injurious effects on fish would be limited to short distances. Also, many of the fish that might otherwise be within the injury-radius are likely to be displaced from this region prior to the approach of the airguns through avoidance reactions to the passing seismic vessel or to the airgun sounds as received at distances beyond the injury radius.

Short, sharp sounds can cause overt or subtle changes in fish behavior. Chapman and Hawkins (1969) tested the reactions of whiting (hake) in the field to an airgun. When the airgun was discharged, the fish dove from 25 to 55 m (80–180 ft) depth and formed a compact layer. By the end of an hour of exposure to the sound pulses, the fish had habituated; they rose in the water despite the continued presence of the sound pulses. However, they began to descend again when the airgun resumed firing after it had stopped. The whiting dove when received sound levels were higher than 178 dB re 1 μPa (peak pressure[2]) (Pearson et al. 1992).

Pearson et al. (1992) conducted a controlled experiment to determine effects of strong noise pulses on several species of rockfish off the California coast. They used an airgun with a source level of 223 dB re 1 μPa. They noted

- startle responses at received levels of 200–205 dB re 1 μPa (peak pressure) and above for two sensitive species, but not for two other species exposed to levels up to 207 dB;
- alarm responses at 177–180 dB (peak) for the two sensitive species, and at 186 to 199 dB for other species;
- an overall threshold for the above behavioral response at about 180 dB (peak pressure);
- an extrapolated threshold of about 161 dB (peak) for subtle changes in the behavior of rockfish; and
- a return to pre-exposure behaviors within the 20–60 min exposure period.

In other airgun experiments, catch per unit effort (CPUE) of demersal fish declined when airgun pulses were emitted (Dalen and Raknes 1985; Dalen and Knutsen 1986; Skalski et al. 1992). Reductions in the catch may have resulted from a change in behavior of the fish. The fish schools descended to near the bottom when the airgun was firing, and the fish may have changed their swimming and schooling behavior. Fish behavior returned to normal minutes after the sounds ceased. In the Barents Sea abundance of cod and haddock measured acoustically was reduced by 44% within 9.2 km (5.0 n.mi.) of an area where airguns operated (Engås et al. 1993). Actual catches declined by 50% throughout the trial area and 70% within the shooting area. This reduction in catch decreased with increasing distance to 30–33 km (16.2–17.8 n.mi.) where catches were unchanged.

Other recent work concerning behavioral reactions of fish to seismic surveys, and concerning effects of seismic surveys on fishing success, is reviewed in Turnpenny and Nedwell (1994), Santulli et al. (1999), Hirst and Rodhouse (2000), Thomson et al. (2001), Wardle et al. (2001), and Engås and Løkkeborg (2002).

In summary, fish often react to sounds, especially strong and/or intermittent sounds of low frequency. Sound pulses at received levels of 160 dB re 1 μPa (peak) may cause subtle changes in behavior. Pulses at levels of 180 dB (peak) may cause noticeable changes in behavior (Chapman and Hawkins 1969; Pearson et al. 1992; Skalski et al. 1992). It also appears that fish often habituate to repeated strong sounds rather rapidly, on time scales of minutes to an hour. However, the habituation does not endure, and resumption of the disturbing activity may again elicit disturbance responses from the same fish.

Fish near the airguns are likely to dive or exhibit some other kind of behavioral response. This might have short-term impacts on the ability of cetaceans to feed near the survey area. However, only a small fraction of the available habitat would be ensonified at any given time, and fish species would return to their pre-disturbance behavior once the seismic activity ceased. Thus, the proposed surveys would have little impact on the abilities of marine mammals to feed in the area where seismic work is

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[2] For airgun pulses, root-mean-square (rms) pressures, averaged over the pulse duration, are on the order of 10–13 dB less than peak pressure (Greene 1997; McCauley et al. 1998, 2000b).

planned. Some of the fish that do not avoid the approaching airguns (probably a small number) may be subject to auditory or other injuries.

Zooplankters that are very close to the source may react to the shock wave. These animals have an exoskeleton and no air sacs. Little or no mortality is expected. Many crustaceans can make sounds and some crustacea and other invertebrates have some type of sound receptor. However, the reactions of zooplankters to sound are not known. Some mysticetes feed on concentrations of zooplankton. A reaction by zooplankton to a seismic impulse would only be relevant to whales if it caused a concentration of zooplankton to scatter. Pressure changes of sufficient magnitude to cause this type of reaction would probably occur only very close to the source. Impacts on zooplankton behavior are predicted to be negligible, and this would translate into negligible impacts on feeding mysticetes.

Because of the reasons noted above, the operations are not expected to cause significant impacts on habitats used by marine mammals, or on the food sources that marine mammals utilize.

X. Anticipated Impact of Loss or Modification of Habitat on Marine Mammals

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

The effects of the planned activity on marine mammal habitats and food resources are expected to be negligible, as described above. A small minority of the marine mammals that are present near the proposed activity may be temporarily displaced as much as a few kilometers by the planned activity. However, the proposed study area off Oregon is not known to be a critical feeding or calving area for any of the species that are found there. Therefore, the proposed activity is not expected to have any habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations.

XI. Mitigation Measures

For the proposed seismic survey off Oregon in July 2004, L-DEO will deploy a 10- or 12-airgun array as an energy source, with discharge volumes of 3050 in^3 and 3705 in^3, respectively. Individual airguns will range in size from 80 to 850 in^3. The airguns in the arrays will be spread out horizontally so the energy from the array will be directed mostly downward. The directional nature of the arrays to be used in this project is an important mitigating factor. This directionality will result in reduced sound levels at any given horizontal distance as compared with the levels expected at that distance if the source were omnidirectional with the stated nominal source level. The modeled sound pressure fields of each of the array configurations to be used during the proposed survey are shown in Figures 6 and 7.

The size of the airgun arrays (which are smaller than the 20-gun array used for some other surveys) is another inherent and important mitigation measure that will reduce the potential for effects relative to those that might occur with a larger array of airguns. Also, the fact that this project is to occur in deep water is also an inherent mitigation measure; the measured sound levels at various distances from the airguns towed by the *Ewing* tended to be lower in deep than in shallower water (Tolstoy et al. 2004).

Received sound levels have been modeled by L-DEO in relation to distance and direction from two arrays. The radii around the 10-airgun array where the received levels would be 180 dB and 190 dB re 1 μPa (rms) were estimated as 550 m (1805 ft) and 200 m (656 ft), respectively. For the 12-airgun array, the radii around the array where the received levels would be 180 dB and 190 dB re 1 μPa (rms) were estimated as 600 m (1969 ft) and 200 m (656 ft), respectively. The 180 and 190 dB shutdown criteria, applicable to cetaceans and pinnipeds, respectively, are specified by NMFS (2000).

Vessel-based observers will watch for marine mammals near the array when it is in use. L-DEO proposes to power down the airguns if marine mammals are detected within the proposed safety radii. Also, L-DEO proposes to use a ramp-up procedure when commencing operations using the airgun arrays. Ramp up will begin with the smallest gun in the array (80 in^3). Guns will be added in a sequence such that the source level of the array will increase at a rate no greater than 6 dB per 5-min period.

Mitigation and monitoring measures proposed to be implemented for the proposed seismic survey have been developed and refined in cooperation with NMFS during previous L-DEO seismic studies and associated EAs, IHA applications, and IHAs. The mitigation and monitoring measures described herein represent a combination of the procedures required by past IHAs for other L-DEO projects, plus additional mitigation and monitoring measures proposed by L-DEO. These measures are described in detail below.

The number of individual animals expected to be closely approached during the proposed activity will be small in relation to regional population sizes. With the proposed monitoring, ramp-up, and power-down provisions (see below), effects on those individuals are expected to be limited to behavioral disturbance. This is expected to have negligible impacts on the species and stocks.

We are not aware of any mating grounds, areas of concentrated feeding, or other areas of special significance for marine mammals within the planned area of operations during the season of operations.

The following subsections provide more detailed information about the mitigation measures that are an integral part of the planned activity.

Marine Mammal Monitoring

Vessel-based observers will monitor marine mammals near the seismic source vessel during all daytime airgun operations and during any nighttime start ups of the airguns. These observations will provide the real-time data needed to implement some of the key mitigation measures. When marine mammals are observed within, or about to enter, designated safety zones (see below) where there is a possibility of significant effects on hearing or other physical effects, airgun operations will be powered down or shut down if necessary.

- During daylight, vessel-based observers will watch for marine mammals near the seismic vessel during all periods with shooting (including ramp ups), and for a minimum of 30 min prior to the planned start of airgun operations after an extended shut down.
- L-DEO proposes to conduct nighttime as well as daytime operations. Observers dedicated to marine mammal observations will not be on duty during ongoing seismic operations at night. At night, bridge personnel will watch for marine mammals (insofar as practical at night) and will call for the airguns to be powered down if marine mammals are observed in or about to enter the safety radii. If the airguns are ramped up at night, two marine mammal observers will monitor marine mammals near the source vessel for 30 min prior to ramp up using night vision devices.

The proposed monitoring plan is described in detail in § XIII.

Proposed Safety Radii

Based on an acoustic model applied by L-DEO, estimates of the 180 and 190 dB re 1 μPa (rms) distances for the airgun arrays proposed to be used for this project are shown in Table 1 (in § I). Although the discharge volumes of the 10- and 12-airgun arrays to be used during the proposed survey differ slightly from the standard 10- and 12-airgun arrays whose sound fields have been modeled, the planned and standard arrays will not differ significantly in source output, as the number of guns has a greater effect on source output than does discharge volume. Thus, the distances at which specified sound levels will be received are expected to be similar for the standard and proposed arrays. The radius around the 10-airgun array where the received level would be 180 dB re 1 μPa (rms), the safety criterion applicable to cetaceans (NMFS 2000), was estimated as 550 m (1805 ft). The corresponding radius for a received level of 190 dB re 1 μPa (rms), the safety criterion applicable to pinnipeds, was estimated as 200 m (656 ft). For the 12-airgun array, the 180 dB and 190 dB radii were estimated as 600 m (1969 ft) and 200 m (656 ft), respectively.

Empirical data concerning these safety radii have been acquired based on measurements during the acoustic verification study conducted by L-DEO in the northern Gulf of Mexico from 27 May to 3 June 2003 (see separate IHA application, EA, and 90-day report). L-DEO's analysis of the acoustic data from that study (Tolstoy et al. 2004) provides limited measurements in deep water, the situation relevant here. Those data indicate that, for deep water, the model tends to overestimate the received sound levels at a given distance. Until additional data become available, it is proposed that safety radii during airgun operations in deep water, including the planned operations off Oregon, will be the values predicted by L-DEO's model. To date, more conservative (larger) safety radii that are 1.5 times the modeled radii have been used. However, given the measurements (Tolstoy et al. 2004), the modeled radii are already conservative (overestimates) for deep water situations, even without the ×1.5 factor. Conservative radii will not be used during the seismic survey with the 10- or 12-gun array off Oregon.

Airguns will be powered down immediately when cetaceans or pinnipeds are detected within or about to enter the appropriate 180-dB (rms) or 190-dB (rms) radius, respectively. The 180 and 190 dB criteria are consistent with guidelines listed for cetaceans and pinnipeds, respectively, by NMFS (2000) and other guidance by NMFS. L-DEO is aware that NMFS is likely to release new noise-exposure guidelines soon. L-DEO will be prepared to revise its procedures for estimating numbers of mammals "taken", safety radii, etc., as may be required by the new guidelines.

Mitigation During Operations

The following mitigation measures will be adopted during the proposed seismic program, provided that doing so will not compromise operational safety requirements:

1. Speed or course alteration;
2. Power-down procedures
3. Shut-down procedures; and
4. Ramp-up procedures.

Special mitigation measures will be implemented for the North Pacific right whale (*Eubalaena japonica*), as this species is of special concern due to its low population size (see "Shut-down Procedures" below).

Speed or Course Alteration

If a marine mammal is detected outside the safety radius and, based on its position and relative motion, is likely to enter the safety radius, the vessel's speed and/or course may be changed if this is practical while minimizing effects on planned science objectives. The marine mammal activities and movements relative to the seismic vessel will be closely monitored to ensure that the marine mammal does not approach within the safety radius. If the mammal appears likely to enter the safety radius, further mitigative actions will be taken, i.e., either further course alterations or power down of the airguns.

Power-down Procedures

A power down involves decreasing the number of airguns in use such that the radius of the 180-dB (or 190-dB) zone is decreased to the extent that marine mammals are not in the safety zone. A power down may also occur when the vessel is moving from one seismic line to another. (However, during parts of this project, the full airgun array is planned to be operated during line changes—see § I.) During a power down, one airgun will be operated. The continued operation of one airgun is intended to alert marine mammals to the presence of the seismic vessel in the area. In contrast, a shut down occurs when all airgun activity is suspended.

If a marine mammal is detected outside the safety radius but is likely to enter the safety radius, and if the vessel's speed and/or course cannot be changed to avoid having the mammal enter the safety radius, the airguns will be powered down before the mammal is within the safety radius. Likewise, if a mammal is already within the safety zone when first detected, the airguns will be powered down immediately. During a power down, at least one airgun (e.g., 80 in^3) will be operated. If a marine mammal is detected within or near the smaller safety radius around that single airgun (Table 1), all airguns will be shut down (see next subsection).

Following a power down, airgun activity will not resume until the marine mammal has cleared the safety zone. The animal will be considered to have cleared the safety zone if it

- is visually observed to have left the safety zone, or
- has not been seen within the zone for 15 min in the case of small odontocetes and pinnipeds, or
- has not been seen within the zone for 30 min in the case of mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales.

When airgun operations resume following a power down whose duration has exceeded specified limits, the airgun array will be ramped up gradually. Ramp-up procedures are described below.

Shut-down Procedures

During a power down, the operating airgun will be shut down if a marine mammal approaches within the modeled safety radius for the then-operating source, typically a single gun of 80 in^3. Because no calibration measurements have been done to confirm the modeled safety radii for the single gun, conservative radii may be used (1.5 times the modeled safety radius). For an 80 in^3 airgun, the predicted 180-dB distance applicable to cetaceans is 36 m (118 ft) and the x1.5 conservative radius is 54 m (177 ft). The corresponding 190-dB radius applicable to pinnipeds is 13 m (43 ft), with the x1.5 conservative radius being 20 m (66 ft). If a marine mammal is detected within or about to enter the appropriate safety radius around the small source in use during a power down, airgun operations will be entirely shut down. In addition, the airguns will be shut down if a North Pacific right whale is sighted anywhere near the vessel, even if it is located outside the safety radius, because of the rarity and sensitive status of this species.

Airgun activity will not resume until the marine mammal has cleared the safety zone, or until the MMO is confident that the marine mammal has left the vicinity of the vessel. The animal will be considered to have cleared the safety zone if it is visually observed to have left the safety zone, or if it has not been seen within the zone for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes, including sperm, pygmy sperm, dwarf sperm, and beaked whales).

Ramp-up Procedures

A "ramp-up" procedure will be followed when the airgun array begins operating after a specified-duration period without airgun operations. The specified period varies depending on the speed of the source vessel and the size of the airgun array that is being used.

- Under normal operational conditions (vessel speed 4 knots or 7.4 km/h), the *Ewing* would travel 600 m (1969 ft) in ~5 min. The 600 m distance is the calculated 180 dB safety radius for the larger (12-gun) array. Thus a ramp up would be required after a power-down or shut-down period lasting ~5 min or longer if the *Ewing* was traveling at 4 knots and was towing the 10 or 12-airgun array.
- If the towing speed is reduced to 3 knots (5.6 km/h) or less, as sometimes required when maneuvering in shallow water (not a factor here), it is proposed that a ramp-up would be required after a "no shooting" period lasting >7 min. At towing speeds not exceeding 3 knots, the source vessel would travel no more than 600 m (1969 ft) in ~7 min.
- Based on the same calculation, a ramp-up procedure would be required after ~4 min if the speed of the source vessel was 5 knots (9.3 km/h).
- During programs when a smaller airgun array is being used, the specified period would be based on the same calculations using the time taken for the source vessel to travel to the boundary of the 180 dB safety radius for that array.

Ramp up will begin with the smallest gun in the array (80 in^3). Airguns will be added in a sequence such that the source level of the array will increase in steps not exceeding 6 dB per 5-min period over a total duration of ~18 to 20 min. During the ramp-up procedures, the safety zone for the full gun array will be maintained.

If the complete safety radius has not been visible for at least 30 min prior to the start of operations in either daylight or nighttime, ramp up will not commence unless at least one airgun has been operating during the interruption of seismic survey operations. That airgun will have a source level of at least 180 dB re 1 μPa·m (rms). It is likely that the airgun arrays will not be ramped up from a complete shut down at night or in thick fog, because the outer part of the safety zone for those arrays will not be visible during those conditions. If one airgun has operated during a power down period, ramp up to full power will be permissible at night or in poor visibility, on the assumption that marine mammals will be alerted to the approaching seismic vessel by the sounds from the single airgun and could move away if they choose. Ramp up of the airguns will not be initiated if a marine mammal is sighted within or near the applicable safety radii during the day or close to the vessel at night.

XII. PLAN OF COOPERATION

> Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a plan of cooperation or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses. A plan must include the following:
>
> (i) A statement that the applicant has notified and provided the affected subsistence community with a draft plan of cooperation;
>
> (ii) A schedule for meeting with the affected subsistence communities to discuss proposed activities and to resolve potential conflicts regarding any aspects of either the operation or the plan of cooperation;
>
> (iii) A description of what measures the applicant has taken and/or will take to ensure that proposed activities will not interfere with subsistence whaling or sealing; and
>
> (iv) What plans the applicant has to continue to meet with the affected communities, both prior to and while conducting activity, to resolve conflicts and to notify the communities of any changes in the operation.

Not applicable. The proposed activity will take place in the NPO off Oregon, and no activities will take place in or near a traditional Arctic subsistence hunting area.

XIII. MONITORING AND REPORTING PLAN

> The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding...

L-DEO proposes to sponsor marine mammal monitoring during the present project, in order to implement the proposed mitigation measures that require real-time monitoring, and to satisfy the anticipated monitoring requirements of the Incidental Harassment Authorization.

L-DEO's proposed Monitoring Plan is described below. L-DEO understands that this Monitoring Plan will be subject to review by NMFS, and that refinements may be required.

The monitoring work described here has been planned as a self-contained project independent of any other related monitoring projects that may be occurring simultaneously in the same regions. L-DEO is prepared to discuss coordination of its monitoring program with any related work that might be done by other groups insofar as this is practical and desirable.

Vessel-based Visual Monitoring

At least two observers dedicated to marine mammal observations will be stationed aboard L-DEO's seismic survey vessel for the seismic survey off Oregon. Observers will be appointed by L-DEO with NMFS concurrence.

It is proposed that one or two MMOs aboard the seismic vessel will search for and observe marine mammals whenever airgun operations are in progress during daylight hours. When feasible, observations will also be made during daytime periods without airgun operations.

Two observers will be on duty for 30 min prior to the start of airgun operations after an extended shut down and during ramp ups. The 30-min observation period is only required prior to commencing seismic survey operations following a shut down of the airgun array for more than 1 hr. After 30 min of observation, the ramp-up procedure will be followed.

If ramp-up procedures must be performed at night, two MMOs will be on duty starting at least 30 min prior to the start of airgun operations and continuing during the subsequent ramp-up procedures. Ramp-up procedures will not commence at night or during the day in poor visibility unless at least one airgun has been operating during the preceding interruption of seismic survey operations. Other than the specified periods mentioned above, no observers will be required to be on duty during seismic operations at night. However, L-DEO bridge personnel (port and starboard seamen and one mate) will assist in marine mammal observations whenever possible, and especially during operations at night, when designated MMOs will not normally be on duty. At least one MMO will be on "standby" at night, in case bridge personnel see a marine mammal. Two image-intensifying night-vision devices (NVDs) will be available for use at night. These are ITT Industries Night Quest NQ220 "Night Vision Viewer" devices, equipped with a 3x magnification lens. The NQ220 is a Generation III binocular NVD.

If the airguns are powered down, observers will continue to maintain watch to determine when the animal is outside the safety radius. Ramp up of the airguns will occur after the observer has determined that the animal has cleared the safety zone. A mammal will be assumed to be clear of the safety zone if it is visually observed to have left that zone, or if it has not been seen within the zone for 15 min (small odontocetes and pinnipeds) or 30 min (mysticetes and large odontocetes). For this purpose, "large odontocetes" will include sperm, pygmy sperm, dwarf sperm, and beaked whales.

Figures 8 and 9 summarize the decision-making sequence that will apply during daylight and darkness, respectively.

The MMOs will watch for marine mammals from the highest practical vantagepoint on the vessel, which is either the bridge or the flying bridge. On the bridge of the *Ewing*, the observer's eye level will be 11 m (36 ft) above sea level, allowing for good visibility within a 210º arc. If observers are stationed on the flying bridge, the eye level will be 14.4 m (47.2 ft) above sea level. During daytime, the MMOs will systematically scan the area around the vessel with reticle binoculars (e.g., 7 × 50 Fujinon). At night, night vision equipment will be available, if required. Laser rangefinding binoculars (Leica LRF 1200 laser rangefinder or equivalent) will be available to assist with distance estimation. These are useful in training observers to estimate distances visually, but are generally not useful in measuring distances to marine mammals directly. If a marine mammal is seen well outside the safety radius, the vessel may be maneuvered to avoid having the mammal come within the safety radius (see Section XI, "Mitigation", above). When mammals are detected within or about to enter the designated safety radii, the airguns will be powered down immediately. The observer(s) will continue to maintain watch to determine when the animal is outside the safety radius. Airgun operations will not resume until the animal is observed to be outside the safety radius or until the specified intervals (15 or 30 min) have passed without a re-sighting.

The vessel-based monitoring will provide data required to estimate the numbers of marine mammals exposed to various received sound levels, to document any apparent disturbance reactions, and thus to estimate the numbers of mammals potentially "taken" by harassment. It will also provide the information needed in order to shut down the airguns at times when mammals are present in or near the safety zone. When a mammal sighting is made, the following information about the sighting will be recorded:

1. Species, group size, age/size/sex categories (if determinable), behavior when first sighted and after initial sighting, heading (if consistent), bearing and distance from seismic vessel, sighting cue, apparent reaction to seismic vessel (e.g., none, avoidance, approach, paralleling, etc.), and behavioral pace.
2. Time, location, heading, speed, activity of the vessel (shooting or not), sea state, visibility, cloud cover, and sun glare.

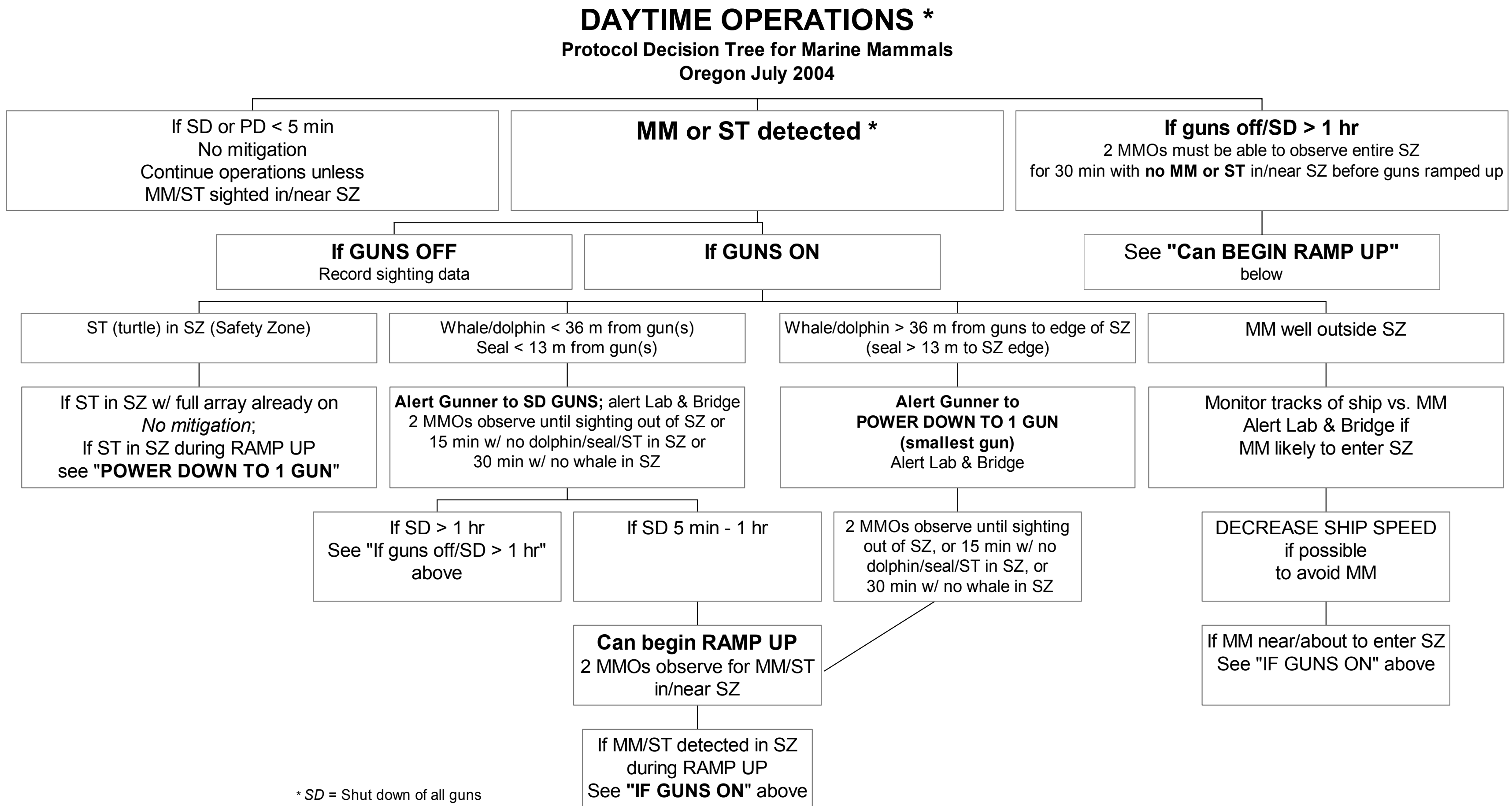
The data listed under (2) will also be recorded at the start and end of each observation watch and during a watch, whenever there is a change in one or more of the variables.

All mammal observations and airgun shut downs will be recorded in a standardized format. Data will be entered into a custom database using a laptop computer when observers are off-duty. The accuracy of the data entry will be verified by computerized validity checks as the data are entered and by subsequent manual and computer checking of the database. These procedures will allow initial summaries of data to be prepared during and shortly after the field program, and will facilitate transfer of the data to statistical, graphical or other programs for further processing and archiving.

Observers will be on duty in shifts of duration no longer than 4 hours. A second observer will also be on watch part of the time, including the 30-min periods preceding startup of the airguns and during ramp ups. Use of two simultaneous observers will increase the proportion of the marine mammals present near the source vessel that are detected. Bridge personnel additional to the dedicated MMOs will also assist in detecting marine mammals and implementing mitigation requirements, and before the start of the seismic survey will be given additional instruction in how to do so. (Most if not all bridge personnel will have had previous experience of this type during prior cruises aboard the *Ewing.*)

Results from the vessel-based observations will provide

1. The basis for real-time mitigation (airgun power down or shut down if necessary).
2. Information needed to estimate the number of marine mammals potentially taken by harassment, which must be reported to NMFS.
3. Data on the occurrence, distribution, and activities of marine mammals in the area where the seismic survey is conducted.
4. Information to compare the distance and distribution of marine mammals relative to the source vessel at times with and without seismic activity.
5. Data on the behavior and movement patterns of marine mammals seen at times with and without seismic activity.



* *SD* = Shut down of all guns
PD = Power down to 1 gun
MM = Marine mammal (whale, dolphin, or seal)
ST = Sea turtle
MMO = Marine mammal observer
SZ = Safety Zone (180 dB for whale/dolphins; 190 dB for pinnipeds and turtles):
SZ for Whales/Dolphins: 550 m for 10-gun array, 600 m for 12-gun array, 36 m for 1-gun
SZ for Pinnipeds & Sea Turtles: 200 m for 10- and 12-gun array, 13 m for 1 gun

FIGURE 14. Flow diagram to aid in implementing ***daytime*** mitigation and monitoring required by the IHA during L-DEO's July 2004 Oregon seismic study.

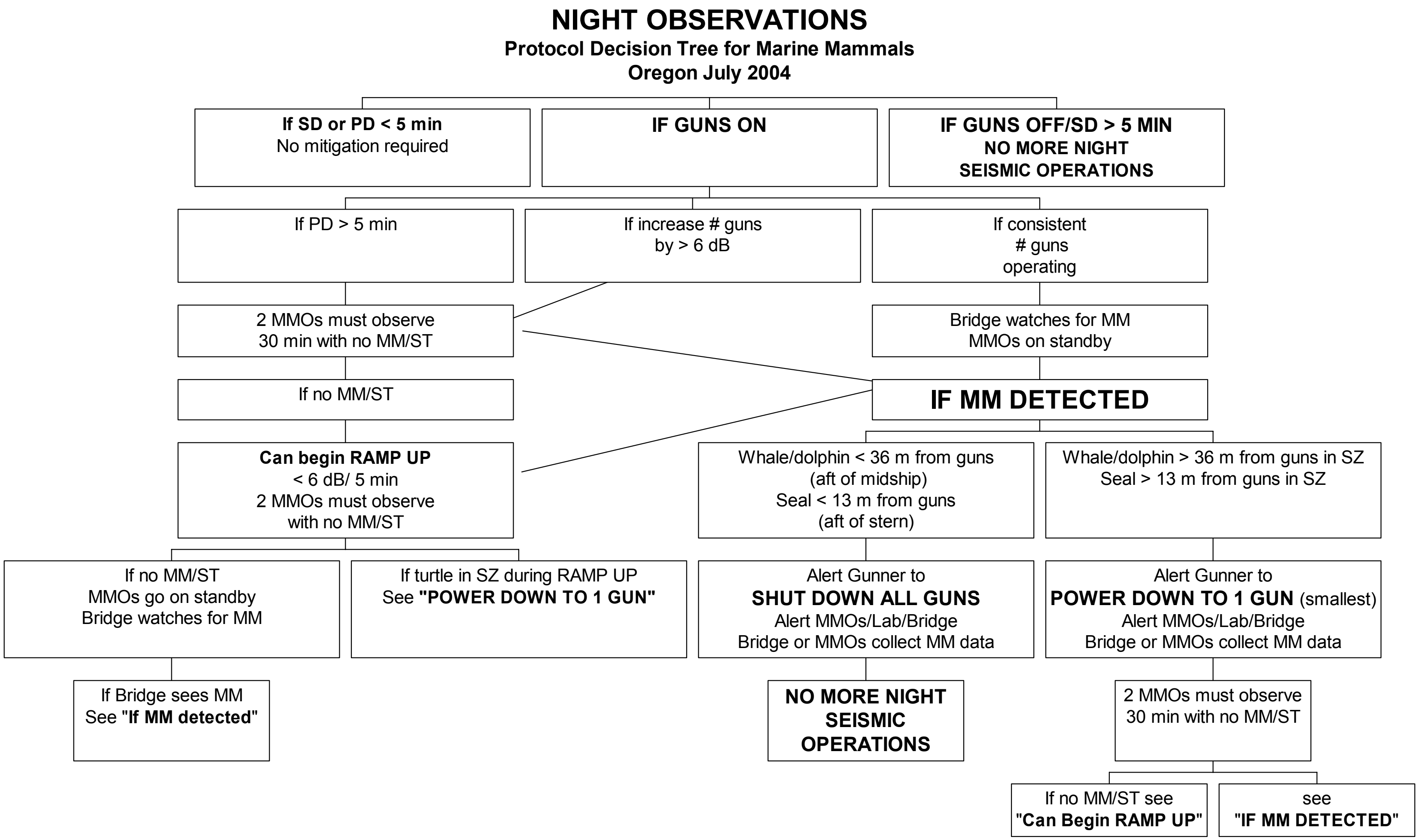


FIGURE 15. Flow diagram to aid in implementing ***nighttime*** mitigation and monitoring required by the IHA for L-DEO's July 2004 Oregon seismic study.

Reporting

A report will be submitted to NMFS within 90 days after the end of the cruise. The end of this 2004 Oregon seismic survey is predicted to occur 23 July 2004. The report will describe the operations that were conducted and the marine mammals that were detected near the operations. The report will be submitted to NMFS, providing full documentation of methods, results, and interpretation pertaining to all monitoring. The 90-day report will summarize the dates and locations of airgun operations, marine mammal sightings (dates, times, locations, activities, associated seismic survey activities), and estimates of the amount and nature of potential "take" of marine mammals by harassment or in other ways.

XIV. Coordinating Research to Reduce and Evaluate Incidental Take

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

L-DEO will coordinate the planned project with other parties that may or are planning to sponsor, conduct or participate in marine mammal, acoustical, and oceanographic studies in the same region during the corresponding part of 2004. These groups could include NMFS, Minerals Management Service, NSF, and others.

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APPENDIX A:

REVIEW OF POTENTIAL IMPACTS OF AIRGUN SOUNDS ON MARINE MAMMALS [3]

The following subsections review relevant information concerning the potential effects of airgun sounds on marine mammals. This information is included here as background for the briefer summary of this topic included in § VI / VII of the IHA Application. This background material is little changed from corresponding subsections included in IHA Applications and EAs submitted to NMFS during 2003 for other L-DEO projects. Those documents concerned L-DEO projects in the following areas: northern Gulf of Mexico, Hess Deep in the eastern tropical Pacific, Norway, Mid-Atlantic Ocean, Bermuda, Southeast Caribbean, and southern Gulf of Mexico (Yucatan Peninsula). Much of this information has also been included in varying formats in other reviews, assessments, and regulatory applications prepared by LGL Ltd., environmental research associates. Because this review is intended to be of general usefulness, it includes references to types of marine mammals that will not be found in some specific regions.

(a) Categories of Noise Effects

The effects of noise on marine mammals are highly variable, and can be categorized as follows (based on Richardson et al. 1995):

1. The noise may be too weak to be heard at the location of the animal, i.e., lower than the prevailing ambient noise level, the hearing threshold of the animal at relevant frequencies, or both;
2. The noise may be audible but not strong enough to elicit any overt behavioral response, i.e., the mammals may tolerate it;
3. The noise may elicit behavioral reactions of variable conspicuousness and variable relevance to the well being of the animal; these can range from subtle effects on respiration or other behaviors (detectable only by statistical analysis) to active avoidance reactions;
4. Upon repeated exposure, animals may exhibit diminishing responsiveness (habituation), or disturbance effects may persist; the latter is most likely with sounds that are highly variable in characteristics, unpredictable in occurrence, and associated with situations that the animal perceives as a threat;
5. Any man-made noise that is strong enough to be heard has the potential to reduce (mask) the ability of marine mammals to hear natural sounds at similar frequencies, including calls from conspecifics, echolocation sounds of odontocetes, and environmental sounds such as surf noise or (at high latitudes) ice noise. However, intermittent airgun or sonar pulses could cause masking for only a small proportion of the time, given the short duration of these pulses relative to the inter-pulse intervals;

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[3] By **W. John Richardson** and **Valerie D. Moulton**, LGL Ltd., environmental research associates. Revised November 2003.

6. Very strong sounds have the potential to cause temporary or permanent reduction in hearing sensitivity, or other physical effects. Received sound levels must far exceed the animal's hearing threshold for any temporary threshold shift to occur. Received levels must be even higher for a risk of permanent hearing impairment.

(b) Hearing Abilities of Marine Mammals

The hearing abilities of marine mammals are functions of the following (Richardson et al. 1995; Au et al. 2000):

1. Absolute hearing threshold at the frequency in question (the level of sound barely audible in the absence of ambient noise).
2. Critical ratio (the signal-to-noise ratio required to detect a sound at a specific frequency in the presence of background noise around that frequency).
3. The ability to localize sound direction at the frequencies under consideration.
4. The ability to discriminate among sounds of different frequencies and intensities.

Marine mammals rely heavily on the use of underwater sounds to communicate and to gain information about their surroundings. Experiments also show that they hear and may react to many man-made sounds including sounds made during seismic exploration.

Toothed Whales

Hearing abilities of some toothed whales (odontocetes) have been studied in detail (reviewed in Chapter 8 of Richardson et al. [1995] and in Au et al. [2000]). Hearing sensitivity of several species has been determined as a function of frequency. The small to moderate-sized toothed whales whose hearing has been studied have relatively poor hearing sensitivity at frequencies below 1 kHz, but extremely good sensitivity at, and above, several kHz. There are at present no specific data on the absolute hearing thresholds of most of the larger, deep-diving toothed whales, such as the sperm and beaked whales.

Despite the relatively poor sensitivity of small odontocetes at the low frequencies that contribute most of the energy in pulses of sound from airgun arrays, the sounds are sufficiently strong that their received levels sometimes remain above the hearing thresholds of odontocetes at distances out to several tens of kilometers (Richardson and Würsig 1997). However, there is no evidence that small odontocetes react to airgun pulses at such long distances, or even at intermediate distances where sound levels are well above the ambient noise level (see below).

The multibeam sonar operated from the *Ewing* emits pulsed sounds at 15.5 kHz. That frequency is within or near the range of best sensitivity of many odontocetes. Thus, sound pulses from the multibeam sonar will be readily audible to these animals when they are within the narrow angular extent of the transmitted sound beam.

Baleen Whales

The hearing abilities of baleen whales have not been studied directly. Behavioral and anatomical evidence indicates that they hear well at frequencies below 1 kHz (Richardson et al. 1995; Ketten 2000). Baleen whales also reacted to sonar sounds at 3.1 kHz and other sources centered at 4 kHz (see Richardson et al. 1995 for a review). Some baleen whales react to pinger sounds up to 28 kHz, but not to pingers or sonars emitting sounds at 36 kHz or above (Watkins 1986). In addition, baleen whales produce sounds at frequencies up to 8 kHz and, for humpbacks, to >15 kHz (Au et al. 2001). The anatomy of the baleen whale inner ear seems to be well adapted for detection of low-frequency sounds (Ketten 1991, 1992, 1994, 2000). The absolute sound levels that they can detect below 1 kHz are probably limited by increasing levels of natural ambient noise at decreasing frequencies. Ambient noise energy is higher at low frequencies than at mid frequencies. At frequencies below 1 kHz, natural ambient levels tend to increase with decreasing frequency.

The hearing systems of baleen whales are almost certainly more sensitive to low-frequency sounds than are the ears of the small toothed whales. Thus, baleen whales are likely to hear airgun pulses farther away than can small toothed whales and, at closer distances, airgun sounds may seem more prominent to baleen than to toothed whales. However, baleen whales have commonly been seen well within the distances where seismic (or sonar) sounds would be detectable and yet often show no overt reaction to those sounds. Behavioral responses by baleen whales to seismic pulses have been documented, but received levels of pulsed sounds necessary to elicit behavioral reactions are typically well above the minimum detectable levels (Malme et al. 1984, 1988; Richardson et al. 1986, 1995; McCauley et al. 2000a; Johnson 2002).

Pinnipeds

Underwater audiograms have been obtained using behavioral methods for three species of phocinid seals, two species of monachid seals, two species of otariids, and the walrus (reviewed in Richardson et al. 1995: 211*ff*; Kastak and Schusterman 1998, 1999; Kastelein et al. 2002). In comparison with odontocetes, pinnipeds tend to have lower best frequencies, lower high-frequency cutoffs, higher auditory sensitivity at low frequencies, and poorer sensitivity at the best frequency.

At least some of the phocid (hair) seals have better sensitivity at low frequencies (≤1 kHz) than do odontocetes. Below 30–50 kHz, the hearing thresholds of most species tested are essentially flat down to about 1 kHz, and range between 60 and 85 dB re 1 µPa. Measurements for a harbor seal indicate that, below 1 kHz, its thresholds deteriorate gradually to ~97 dB re 1 µPa at 100 Hz (Kastak and Schusterman 1998). The northern elephant seal (not an Atlantic/Gulf of Mexico species) appears to have better underwater sensitivity than the harbor seal, at least at low frequencies (Kastak and Schusterman 1998, 1999).

For the otariid (eared) seals, the high frequency cutoff is lower than for phocinids, and sensitivity at low frequencies (e.g., 100 Hz) is poorer than for hair seals (harbor or elephant seal).

The underwater hearing of a walrus has recently been measured at frequencies from 125 Hz to 15 kHz (Kastelein et al. 2002). The range of best hearing was from 1–12 kHz, with maximum sensitivity (67 dB re 1 µPa) occurring at 12 kHz (Kastelein et al. 2002).

Sirenians

The hearing of manatees is sensitive at frequencies below 3 kHz. A West Indian manatee that was tested using behavioral methods could apparently detect sounds from 15 Hz to 46 kHz (Gerstein et al. 1999). Thus, manatees may hear, or at least detect, sounds in the low-frequency range where most seismic energy is released. It is possible that they are able to feel these low-frequency sounds using vibrotactile receptors or because of resonance in body cavities or bone conduction.

Based on measurements of evoked potentials, manatee hearing is apparently best around 1–1.5 kHz (Bullock et al. 1982). However, behavioral testing suggests their best sensitivity is at 6 to 20 kHz (Gerstein et al. 1999). The ability to detect high frequencies may be an adaptation to shallow water, where the propagation of low frequency sound is limited (Gerstein et al. 1999).

(c) Characteristics of Airgun Pulses

Airguns function by venting high-pressure air into the water. The pressure signature of an individual airgun consists of a sharp rise and then fall in pressure, followed by several positive and negative pressure excursions caused by oscillation of the resulting air bubble. The sizes, arrangement, and firing times of the individual airguns in an array are designed and synchronized to suppress the pressure oscillations subsequent to the first cycle. The resulting downward-directed pulse has a duration of only 10 to 20 ms, with only one strong positive and one strong negative peak pressure (Caldwell and Dragoset 2000). Most energy emitted from airguns is at relatively low frequencies. For example, typical high-energy airgun arrays emit most energy at 10–120 Hz. However, the pulses contain some energy up to 500–1000 Hz and above (Goold and Fish 1998). The pulsed sounds associated with seismic exploration have higher peak levels than other industrial sounds to which whales and other marine mammals are routinely exposed. The only sources with higher or comparable effective source levels are explosions.

The peak-to-peak source levels of the 2- to 20-airgun arrays used by L-DEO during various projects range from 236 to 263 dB re 1 μPa at 1 m, considering the frequency band up to about 250 Hz. These are the nominal source levels applicable to downward propagation. The effective source levels for horizontal propagation are lower. The only man-made sources with effective source levels as high as (or higher than) a large array of airguns are explosions and high-power sonars operating near maximum power.

Several important mitigating factors need to be kept in mind. ***(1)*** Airgun arrays produce intermittent sounds, involving emission of a strong sound pulse for a small fraction of a second followed by several seconds of near silence. In contrast, some other sources produce sounds with lower peak levels, but their sounds are continuous or discontinuous but continuing for much longer durations than seismic pulses. ***(2)*** Airgun arrays are designed to transmit strong sounds downward through the seafloor, and the amount of sound transmitted in near-horizontal directions is considerably reduced. Nonetheless, they also emit sounds that travel horizontally toward non-target areas. ***(3)*** An airgun array is a distributed source, not a point source. The nominal source level is an estimate of the sound that would be measured from a theoretical point source emitting the same total energy as the airgun array. That figure is useful in calculating the expected received levels in the far field, i.e., at moderate and long distances. Because the airgun array is not a single point source, there is no one location within the near field (or anywhere else) where the received level is as high as the nominal source level.

The strengths of airgun pulses can be measured in different ways, and it is important to know which method is being used when interpreting quoted source or received levels. Geophysicists usually quote peak-to-peak levels, in bar-meters or dB re 1 μPa·m. The peak (= zero-to-peak) level for the same pulse is typically about 6 dB less. In the biological literature, levels of received airgun pulses are often described based on the "average" or "root-mean-square" (rms) level over the duration of the pulse. The rms value for a given airgun pulse is typically about 10 dB lower than the peak level, and 16 dB lower than the peak-to-peak value (Greene 1997; McCauley et al. 1998, 2000a). A fourth measure that is sometimes used is the energy level, in dB re 1 $\mu Pa^2 \cdot s$. Because the pulses are <1 s in duration, the numerical value of the energy is lower than the rms pressure level, but the units are different. Because the level of a given pulse will differ substantially depending on which of these measures is being applied, it is important to be aware which measure is in use when interpreting any quoted pulse level. In the past, NMFS has commonly referred to rms levels when discussing levels of pulsed sounds that might "harass" marine mammals.

Seismic sound received at any given point will arrive via a direct path, indirect paths that include reflection from the sea surface and bottom, and often indirect paths including segments through the bottom sediments. Sounds propagating via indirect paths travel longer distances and often arrive later than sounds arriving via a direct path. (However, sound traveling in the bottom may travel faster than that in the water, and thus may, in some situations, arrive slightly earlier than the direct arrival despite traveling a greater distance.) These variations in travel time have the effect of lengthening the duration of the received pulse. Near the source, the predominant part of a seismic pulse is about 10 to 20 ms in duration. In comparison, the pulse duration as received at long horizontal distances can be much greater. For example, for one airgun array operating in the Beaufort Sea, pulse duration was about 300 ms at a distance of 8 km (4.3 n.mi.), 500 ms at 20 km (10.8 n.mi.), and 850 ms at 73 km or 39.4 n.mi. (Greene and Richardson 1988).

Another important aspect of sound propagation is that received levels of low-frequency underwater sounds diminish close to the surface because of pressure-release and interference phenomena that occur at and near the surface (Urick 1983; Richardson et al. 1995). Paired measurements of received airgun sounds at depths of 3 m (9.8 ft) vs. 9 m (29.5 ft) or 18 m (59 ft) have shown that received levels are typically several decibels lower at 3 m (Greene and Richardson 1988). For a mammal whose auditory organs are within 0.5 or 1 m (1.6–3.3 ft) of the surface, the received level of the predominant low-frequency components of the airgun pulses would be further reduced. In deep water, the received levels at deep depths can be considerably higher than those at relatively shallow (e.g., 18 m) depths and the same horizontal distance from the airguns (L-DEO in prep.).

Pulses of underwater sound from open-water seismic exploration are often detected 50–100 km (27–54 n.mi.) from the source location, even during operations in nearshore waters (Greene and Richardson 1988; Burgess and Greene 1999). At those distances, the received levels are low—below 120 dB re 1 μPa on an approximate rms basis. However, faint seismic pulses are sometimes detectable at even greater ranges (e.g., Bowles et al. 1994; Fox et al. 2002). Considerably higher levels can occur at distances out to several kilometers from an operating airgun array.

(d) Masking Effects of Seismic Surveys

Masking effects of pulsed sounds on marine mammal calls and other natural sounds are expected to be limited, although there are few specific data on this. Some whales are known to continue calling in the presence of seismic pulses. Their calls can be heard between the seismic pulses (e.g., Richardson et al. 1986; McDonald et al. 1995; Greene et al. 1999). Although there has been one report that sperm whales cease calling when exposed to pulses from a very distant seismic ship (Bowles et al. 1994), a recent study reports that sperm whales off northern Norway continued calling in the presence of seismic pulses (Madsen et al. 2002). Masking effects of seismic pulses are expected to be negligible in the case of the smaller odontocete cetaceans, given the intermittent nature of seismic pulses plus the fact that sounds important to them are predominantly at much higher frequencies than are airgun sounds.

Most of the energy in the sound pulses emitted by airgun arrays is at low frequencies, with strongest spectrum levels below 200 Hz and considerably lower spectrum levels above 1000 Hz. These low frequencies are mainly used by mysticetes, but generally not by odontocetes, pinnipeds, or sirenians. An industrial sound source will reduce the effective communication or echolocation distance only if its frequency is close to that of the marine mammal signal. If little or no overlap occurs between the industrial noise and the frequencies used, as in the case of many marine mammals vs. airgun sounds, communication and echolocation are not expected to be disrupted. Furthermore, the discontinuous nature of seismic pulses makes significant masking effects unlikely even for mysticetes.

A few cetaceans are known to increase the source levels of their calls in the presence of elevated sound levels, or possibly to shift their peak frequencies in response to strong sound signals (Dahlheim 1987; Au 1993; Lesage et al. 1999; Terhune 1999; reviewed in Richardson et al. 1995:233*ff,* 364*ff*). These studies involved exposure to other types of anthropogenic sounds, not seismic pulses, and it is not known whether these types of responses ever occur upon exposure to seismic sounds. If so, these adaptations, along with directional hearing and preadaptation to tolerate some masking by natural sounds (Richardson et al. 1995), would all reduce the importance of masking.

(e) Disturbance by Seismic Surveys

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. In the terminology of the 1994 amendments to the MMPA, seismic noise could cause "Level B" harassment of certain marine mammals. Level B harassment is defined as "...disruption of behavioral patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering."

There has been debate regarding how substantial a change in behavior or mammal activity is required before the animal should be deemed to be "taken by Level B harassment". NMFS has recently stated that

> "…a simple change in a marine mammal's actions does not always rise to the level of disruption of its behavioral patterns. … If the only reaction to the [human] activity on the part of the marine mammal is within the normal repertoire of actions that are required to carry out that behavioral pattern, NMFS considers [the human] activity not to have caused a disruption of the behavioral pattern, provided the animal's reaction is not otherwise significant enough to be considered disruptive due to length or severity. Therefore, for example, a short-term change in breathing rates or a somewhat shortened or lengthened dive sequence that are within the animal's normal range and that do not have any biological significance (i.e., do no disrupt the animal's overall behavioral pattern of breathing under the circumstances), do not rise to a level requiring a small take authorization." (NMFS 2001, p. 9293).

Based on this guidance from NMFS, we assume that simple exposure to sound, or brief reactions that do not disrupt behavioral patterns in a potentially significant manner, do not constitute harassment or "taking". By potentially significant, we mean "in a manner that might have deleterious effects to the well-being of individual marine mammals or their populations".

Even with this guidance, there are difficulties in defining what marine mammals should be counted as "taken by harassment". For many species and situations, we do not have detailed information about their reactions to noise, including reactions to seismic (and sonar) pulses. Behavioral reactions of marine mammals to sound are difficult to predict. Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, and many other factors. If a marine mammal does react to an underwater sound by changing its behavior or moving a small distance, the impacts of the change may not be significant to the individual let alone the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be significant. Given the many uncertainties in predicting the quantity and types of impacts of noise on marine mammals, it is common practice to estimate how many mammals were present within a particular distance of industrial activities, or exposed to a particular level of industrial sound. This likely overestimates the numbers of marine mammals that are affected in some biologically important manner.

The definitions of "taking" in the U.S. Marine Mammal Protection Act, and its applicability to various activities, are presently (autumn 2003) under active consideration by the U.S. Congress. Some changes are likely. Also, the U.S. National Marine Fisheries Service is considering the adoption of new criteria concerning the noise exposures that are (and are not) expected to cause "takes" of various types. Thus, for projects subject to U.S. jurisdiction, changes in procedures may be required in the near future.

The sound criteria used to estimate how many marine mammals might be disturbed to some biologically-important degree by a seismic program are based on behavioral observations during studies of several species. However, information is lacking for many species. Detailed studies have been done on humpback, gray and bowhead whales, and on ringed seals. Less detailed data are available for some other species of baleen whales, sperm whales, and small toothed whales.

Baleen Whales

Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, baleen whales exposed to strong noise pulses from airguns often react by deviating from their normal migration route and/or interrupting their feeding and moving away. Some of the main studies on this topic are the following: Malme et al. 1984, 1985, 1988; Richardson et al. 1986, 1995, 1999; Ljungblad et al. 1988; Richardson and Malme 1993; McCauley et al. 1998, 2000a; Miller et al. 1999.

Prior to the late 1990s, it was thought that bowhead whales, gray whales, and humpback whales all begin to show strong avoidance reactions to seismic pulses at received levels of about 160 to 170 dB re 1 μPa rms, but that subtle behavioral changes sometimes become evident at somewhat lower received levels. Recent studies have shown that some species of baleen whales (bowheads and humpbacks in particular) may show strong avoidance at received levels somewhat lower than 160–170 dB re 1 μPa rms. The observed avoidance reactions involved movement away from feeding locations or statistically significant deviations in the whales' direction of swimming and/or migration corridor as they approached or passed the sound sources. In the case of the migrating whales, the observed changes in behavior appeared to be of little or no biological consequence to the animals—they simply avoided the sound source by displacing their migration route to varying degrees, but within the natural boundaries of the migration corridors.

Humpback Whales.—McCauley et al. (1998, 2000a) studied the responses of humpback whales off Western Australia to a full-scale seismic survey with a 16-airgun 2678-in^3 array, and to a single 20 in^3 airgun with source level 227 dB re 1 μPa·m (p-p). They found that the overall distribution of humpbacks migrating through their study area was unaffected by the full-scale seismic program. McCauley et al. (1998) did, however, document localized avoidance of the array and of the single gun. Avoidance reactions began at 5–8 km (2.7–4.3 n.mi.) from the array and those reactions kept most pods about 3–4 km (1.6–2.2 n.mi.) from the operating seismic boat. Observations were made from the seismic vessel, from which the maximum viewing distance was listed as 14 km (7.6 n.mi.). Avoidance distances with respect to the single airgun were smaller but consistent with the results from the full array in terms of the received sound levels. Mean avoidance distance from the airgun corresponded to a received sound level of 140 dB re 1 μPa rms; this was the level at which humpbacks started to show avoidance reactions to an approaching airgun. The standoff range, i.e., the closest point of approach of the airgun to the whales, corresponded to a received level of 143 dB rms. The initial avoidance response generally occurred at distances of 5–8 km (2.7–4.3 n.mi.) from the airgun array and 2 km (1.1 n.mi.) from the single gun. However, some individual humpback whales, especially males, approached within distances 100–400 m (328–1312 ft), where the maximum received level was 179 dB re 1 μPa rms.

Humpback whales summering in southeast Alaska did not exhibit persistent avoidance when exposed to seismic pulses from a 1.64-L (100 in^3) airgun (Malme et al. 1985). Some humpbacks seemed "startled" at received levels of 150–169 dB re 1 μPa. Malme et al. (1985) concluded that there was no clear evidence of avoidance, despite the possibility of subtle effects, at received levels up to 172 re 1 μPa on an approximate rms basis.

Bowhead Whales.—Bowhead whales on their summering grounds in the Canadian Beaufort Sea showed no obvious reactions to pulses from seismic vessels at distances of 6 to 99 km (3–53 n.mi.) and received sound levels of 107–158 dB on an approximate rms basis (Richardson et al. 1986); their general activities were indistinguishable from those of a control group. However, subtle but statistically significant changes in surfacing–respiration–dive cycles were evident upon statistical analysis. Bowheads usually did show strong avoidance responses when seismic vessels approached within a few kilometers (~3–7 km or 1.6–3.8 n.mi.) and when received levels of airgun sounds were 152–178 dB (Richardson et al. 1986, 1995; Ljungblad et al. 1988). In one case, bowheads engaged in near-bottom feeding began to turn away from a 30-airgun array with a source level of 248 dB re 1 μPa·m at a distance of 7.5 km (4 n.mi.), and swam away when it came within about 2 km (1.1 n.mi.). Some whales continued feeding until the vessel was 3 km (1.6 n.mi.) away. Feeding bowhead whales tend to tolerate higher sound levels than migrating whales before showing an overt change in behavior. The feeding whales may be affected by the sounds, but the need to feed may reduce the tendency to move away.

Migrating bowhead whales in the Alaskan Beaufort Sea seem more responsive to noise pulses from a distant seismic vessel than are summering bowheads. In 1996-98, a partially-controlled study of the effect of Ocean Bottom Cable (OBC) seismic surveys on westward-migrating bowheads was conducted in late summer and autumn in the Alaskan Beaufort Sea (Miller et al. 1999; Richardson et al. 1999). Aerial surveys showed that some westward-migrating whales avoided an active seismic survey boat by 20–30 km (10.8–16.2 n.mi.), and that few bowheads approached within 20 km (10.8 n.mi.). Received sound levels at those distances were only 116–135 dB re 1 μPa (rms). Some whales apparently began to deflect their migration path when still as much as 35 km (19 n.mi.) away from the airguns. At times when the airguns were not active, many bowheads moved into the area close to the inactive seismic vessel. Avoidance of the area of seismic operations did not persist beyond 12–24 h after seismic shooting stopped. These and other data suggest that migrating bowhead whales are more responsive to seismic pulses than were summering bowheads.

Gray Whales.—Malme et al. (1986, 1988) studied the responses of feeding gray whales to pulses from a single 100 in^3 airgun off St. Lawrence Island in the northern Bering Sea. They estimated, based on small sample sizes, that 50% of feeding gray whales ceased feeding at an average received pressure level of 173 dB re 1 μPa on an (approximate) rms basis, and that 10% of feeding whales interrupted feeding at received levels of 163 dB. Malme at al. (1986) estimated that an average pressure level of 173 dB occurred at a range of 2.6 to 2.8 km (1.4–1.5 n.mi.) from an airgun array with a source level of 250 dB (0-pk) in the northern Bering Sea. These findings were generally consistent with the results of experiments conducted on larger numbers of gray whales that were migrating along the California coast. Malme and Miles (1985) concluded that, during migration, changes in swimming pattern occurred for received levels of about 160 dB re 1 μPa and higher, on an approximate rms basis. The 50% probability of avoidance was estimated to occur at a CPA distance of 2.5 km (1.3 n.mi.) from a 4000-in^3 array operating off central

California (CPA = closest point of approach). This would occur at an average received sound level of about 170 dB (rms). Some slight behavioral changes were noted at received sound levels of 140 to 160 dB (rms).

There was no indication that Western gray whales exposed to seismic noise were displaced from their overall feeding grounds near Sakhalin Island during seismic programs in 1997 (Würsig et al. 1999) and in 2001. However, there were indications of subtle behavioral effects and (in 2001) localized avoidance by some individuals (Johnson 2002; Weller et al. 2002).

Rorquals.—Blue, sei, fin, and minke whales have occasionally been reported in areas ensonified by airgun pulses. Sightings by observers on seismic vessels off the U.K. from 1997 to 2000 suggest that, at times of good sightability, numbers of rorquals seen are similar when airguns are shooting and not shooting (Stone 2003). Although individual species did not show any significant displacement in relation to seismic activity, all baleen whales combined were found to remain significantly further from the airguns during shooting compared with periods without shooting (Stone 2003). Baleen whale pods sighted from the ship were found to be at a median distance of about 1.6 km (0.9 n.mi.) from the array during shooting and 1.0 km (0.5 n.mi.) during periods without shooting (Stone 2003). Baleen whales, as a group, made more frequent alterations of course (usually away from the vessel) during shooting compared with periods of no shooting (Stone 2003). In addition, fin/sei whales were less likely to remain submerged during periods of seismic shooting (Stone 2003).

Discussion and Conclusions.—Baleen whales generally tend to avoid operating airguns, but avoidance radii are quite variable. Whales are often reported to show no overt reactions to airgun pulses at distances beyond a few kilometers, even though the airgun pulses remain well above ambient noise levels out to much longer distances. However, recent studies of humpback and especially migrating bowhead whales show that reactions, including avoidance, sometimes extend to greater distances than documented earlier. Avoidance distances often exceed the distances at which boat-based observers can see whales, so observations from the source vessel are biased.

Some baleen whales show considerable tolerance of seismic pulses. However, when the pulses are strong enough, avoidance or other behavioral changes become evident. Because the responses become less obvious with diminishing received sound level, it has been difficult to determine the maximum distance (or minimum received sound level) at which reactions to seismic become evident and, hence, how many whales are affected.

Studies of gray, bowhead, and humpback whales have determined that received levels of pulses in the 160–170 dB re 1 μPa rms range seem to cause obvious avoidance behavior in a substantial fraction of the animals exposed. In many areas, seismic pulses diminish to these levels at distances ranging from 4.5 to 14.5 km (2.4–7.8 n.mi.) from the source. A substantial proportion of the baleen whales within this distance range may show avoidance or other strong disturbance reactions to the seismic array.

Data on short-term reactions (or lack of reactions) of cetaceans to impulsive noises do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect reproductive rate or distribution and habitat use in subsequent days or years. Gray whales continued to migrate annually along the west coast of North America despite intermittent seismic exploration (and much ship traffic) in that area for decades (Appendix A in Malme et al. 1984). Bowhead whales continued to travel to the eastern Beaufort Sea each summer despite seismic exploration in their summer and autumn range for many years. Bowheads were often seen in summering areas where seismic exploration occurred in preceding summers (Richardson et al. 1987). They also have been observed over periods of days or weeks in areas repeatedly ensonified by seismic pulses. However, it is not known whether the same individual bowheads were involved in these repeated observations (within and between years) in strongly ensonified areas. It is also not known whether whales that tolerate exposure to seismic pulses are stressed.

Toothed Whales

Little systematic information is available about reactions of toothed whales to noise pulses. Few studies similar to the more extensive baleen whale/seismic pulse work summarized above have been reported for toothed whales, and none similar in size and scope to the studies of humpback, bowhead and gray whales mentioned above. However, systematic work on sperm whales is underway.

Delphinids and Similar Species.—Seismic operators sometimes see dolphins and other small toothed whales near operating airgun arrays, but in general there seems to be a tendency for most delphinids to show some limited avoidance of operating seismic vessels. Authors reporting cases of small toothed whales close to the operating airguns have included Duncan (1985), Arnold (1996), and Stone (2003). When a 3959 in^3, 18-airgun array was firing off California, toothed whales behaved in a manner similar to that observed when the airguns were silent (Arnold 1996). Most, but not all, dolphins often seemed to be attracted to the seismic vessel and floats, and some rode the bow wave of the seismic vessel regardless of whether the guns were firing. However, in Puget Sound, Dall's porpoises observed when a 6000 in^3, 12–16-airgun array was firing tended to be heading away from the boat (Calambokidis and Osmek 1998).

Goold (1996a,b,c) studied the effects on common dolphins, *Delphinus delphis*, of 2D seismic surveys in the Irish Sea. Passive acoustic surveys were conducted from the "guard ship" that towed a hydrophone 180-m aft. The results indicated that there was a local displacement of dolphins around the seismic operation. However, observations indicated that the animals were tolerant of the sounds at distances outside a 1-km (0.5 n.mi.) radius from the guns (Goold 1996a). Initial reports of larger-scale displacement were later shown to represent a normal autumn migration of dolphins through the area, and were not attributable to seismic surveys (Goold 1996a,b,c).

Observers stationed on seismic vessels operating off the United Kingdom from 1997–2000 have provided data on the occurrence and behavior of various toothed whales exposed to seismic pulses (Stone 2003). Dolphins of various species often showed more evidence of avoidance of operating airgun arrays than has been reported previously for small odontocetes. Sighting rates of white-sided dolphins, white-beaked dolphins, *Lagenorhynchus* spp., and all small odontocetes combined were significantly lower during periods of shooting. Except for pilot whales, all of the small odontocete species tested, including killer whales, were found to be significantly farther from large airgun arrays during periods of shooting compared with periods of no shooting. Pilot whales showed few reactions to seismic activity. The displacement of the median distance from the array was ~0.5 km (0.3 n.mi.) or more for most species groups. Killer whales also appear to be more tolerant of seismic shooting in deeper waters.

For all small odontocete species, except pilot whales, that were sighted during seismic surveys off the United Kingdom in 1997–2000, the numbers of positive interactions with the survey vessel (e.g., bow-riding, approaching the vessel, etc.) were significantly fewer during periods of shooting. All small odontocetes combined showed more negative interactions (e.g., avoidance) during periods of shooting. Small odontocetes, including white-beaked dolphins, *Lagenorhynchus* spp., and other dolphin spp. showed a tendency to swim faster during periods with seismic shooting; *Lagenorhynchus* spp. were also observed to swim more slowly during periods without shooting. Significantly fewer white-beaked dolphins, *Lagenorhynchus* spp., harbor porpoises, and pilot whales traveled towards the vessel and/or more were traveling away from the vessel during periods of shooting.

Captive bottlenose dolphins and beluga whales exhibit changes in behavior when exposed to strong pulsed sounds similar in duration to those typically used in seismic surveys (Finneran et al. 2000, 2002). Finneran et al. (2002) exposed a captive bottlenose dolphin and white whale to single impulses from a watergun (80 in^3). As compared with airgun pulses, water gun impulses were expected to contain proportionally more energy at higher frequencies because there is no significant gas-filled bubble, and thus little low-frequency bubble-pulse energy (Hutchinson and Detrick 1984). The captive animals sometimes vocalized after exposure and exhibited a reluctance to station at the test site where subsequent exposure to impulses would be implemented (Finneran et al. 2002). Similar behaviors were exhibited by captive bottlenose dolphins and a white whale exposed to single underwater pulses designed to simulate those produced by distant underwater explosions (Finneran et al. 2000). It is uncertain what relevance these observed behaviors in captive, trained marine mammals exposed to single sound pulses may have to free-ranging animals exposed to multiple pulses. In any event, the animals tolerated rather high received levels of sound (pk-pk level >200 dB re 1 μPa) before exhibiting the aversive behaviors mentioned above.

Observations of odontocete responses (or lack of responses) to noise pulses from underwater explosions (as opposed to airgun pulses) may be relevant as an indicator of odontocete responses to very strong noise pulses. During the 1950s, small explosive charges were dropped into an Alaskan river in attempts to scare belugas away from salmon. Success was limited (Fish and Vania 1971; Frost et al. 1984). Small explosive charges were "not always effective" in moving bottlenose dolphins away from sites in the Gulf of Mexico where larger demolition blasts were about to occur (Klima et al. 1988). Odontocetes may be attracted to fish killed by explosions, and thus attracted rather than repelled by "scare" charges. Captive false killer whales showed no obvious reaction to single noise pulses from small (10 g) charges; the received level was ~185 dB re 1 μPa (Akamatsu et al. 1993). Jefferson and Curry (1994) reviewed several additional studies that found limited or no effects of noise pulses from small explosive charges on killer whales and other odontocetes. Aside from the potential for TTS, the tolerance to these charges may indicate a lack of effect or the failure to move away may simply indicate a stronger desire to eat, regardless of circumstances.

Beaked Whales.—There are no specific data on the behavioral reactions of beaked whales to seismic surveys. Most beaked whales tend to avoid approaching vessels of other types (e.g., Würsig et al. 1998). They may also dive for an extended period when approached by a vessel (e.g., Kasuya 1986). It is likely that these beaked whales would normally show strong avoidance of an approaching seismic vessel, but this has not been documented explicitly. Northern bottlenose whales sometimes are quite tolerant of slow-moving vessels (Reeves et al. 1993; Hooker et al. 2001). However, those vessels were not emitting airgun pulses.

There are increasing indications that some beaked whales tend to strand when naval exercises, including sonar operation, are ongoing nearby (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998; NOAA and USN 2001; Jepson et al. 2003; see also the "Strandings and Mortality" subsection, later). These strandings are apparently at least in part a disturbance response, although auditory or other injuries may also be a factor. Whether beaked whales would ever react similarly to seismic surveys is unknown. Seismic survey sounds are quite different from those of the sonars in operation during the above-cited incidents. There has been a recent (Sept. 2002) stranding of Cuvier's beaked whales in the Gulf of California (Mexico) when the L-DEO vessel *Maurice Ewing* was conducting a seismic survey in the general area (e.g., Malakoff 2002). There was also an earlier stranding of Cuvier's beaked whales in the Galapagos, during a seismic survey in April 2000; however "There is no obvious mechanism that bridges the distance between this source and the stranding site" (Gentry 2002). The evidence with respect to seismic surveys and beaked whale strandings is inconclusive, and NMFS has not established a link between the Gulf of California stranding and the seismic activities (Hogarth 2002).

Sperm Whales.—All three species of sperm whales have been reported to show avoidance reactions to standard vessels not emitting airgun sounds (e.g., Richardson et al. 1995; Würsig et al. 1998). Thus, it is to be expected that they would tend to avoid an operating seismic survey vessel. There are some limited observations suggesting that sperm whales in the Southern Ocean ceased calling during some (but not all) times when exposed to weak noise pulses from extremely distant (>300 km or 162 n.mi.) seismic exploration (Bowles et al. 1994). This "quieting" was suspected to represent a disturbance effect, in part because sperm whales exposed to pulsed man-made sounds at higher frequencies often cease calling (Watkins and Schevill 1975; Watkins et al. 1985). Also, sperm whales in the Gulf of Mexico may have moved away from a seismic vessel (Mate et al. 1994).

On the other hand, recent (and more extensive) data from vessel-based monitoring programs in U.K. waters suggest that sperm whales in that area show little evidence of avoidance or behavioral disruption in the presence of operating seismic vessels (Stone 2003). These types of observations are difficult to interpret because the observers are stationed on or near the seismic vessel, and may underestimate reactions by some of the more responsive species or individuals, which may be beyond visual range. However, the U.K. results do seem to show considerable tolerance of seismic surveys by at least some sperm whales. Also, a recent study off northern Norway indicated that sperm whales continued to call when exposed to pulses from a distant seismic vessel. Received levels of the seismic pulses were up to 146 dB re 1 μPa pk-pk (Madsen et al. 2002). Similarly, a study conducted off Nova Scotia that analyzed recordings of sperm whale vocalizations at various distances from an active seismic program did not detect any obvious changes in the distribution or behavior of sperm whales (McCall Howard 1999). An experimental study of sperm whale reactions to seismic surveys in the Gulf of Mexico is presently underway (Caldwell 2002; Tyack et al. in press), along with a study of the movements of sperm whales with satellite-linked tags in relation to seismic surveys (Mate in press). During two controlled exposure experiments where sperm whales were exposed to seismic pulses at received levels up to 148 dB re 1 μPa, there was no indication of avoidance of the vessel or changes in feeding efficiency (Tyack et al. in press). The received sounds were measured on an "rms over octave band with most energy" basis (P. Tyack, pers. comm. to LGL Ltd.); the broadband rms value would be somewhat higher. Although the sample size from the initial work was small (four whales during two experiments), the results are consistent with those off northern Norway.

Conclusions.—Dolphins and porpoises are often seen by observers on active seismic vessels, occasionally at close distances (e.g., bow riding). However, some studies, especially near the U.K., show localized avoidance. In contrast, recent studies show little evidence of reactions by sperm whales to airgun pulses, contrary to earlier indications.

There are no specific data on responses of beaked whales to seismic surveys, but it is likely that most if not all species show strong avoidance. There is increasing evidence that some beaked whales may strand after exposure to strong noise from sonars. Whether they ever do so in response to seismic survey noise is unknown.

Pinnipeds

Few studies of the reactions of pinnipeds to noise from open-water seismic exploration have been published (for review, see Richardson et al. 1995). However, pinnipeds have been observed during a number of seismic monitoring studies in recent years. Monitoring studies in the Beaufort Sea during 1996-2001 provide a substantial amount of information on avoidance responses (or lack thereof) and associated behavior. Pinnipeds exposed to seismic surveys have also been observed during recent seismic surveys along the U.S. west coast. Some limited data are available on physiological responses of seals exposed to seismic sound, as studied with the aid of radio telemetry. Also, there are data on the reactions of pinnipeds to various other related types of impulsive sounds.

Early observations provided considerable evidence that pinnipeds are often quite tolerant of strong pulsed sounds. During seismic exploration off Nova Scotia, grey seals exposed to noise from airguns and linear explosive charges reportedly did not react strongly (J. Parsons *in* G.D. Greene et al. 1985). An airgun caused an initial startle reaction among South African fur seals but was ineffective in scaring them away from fishing gear (Anonymous 1975). Pinnipeds in both water and air sometimes tolerate strong noise pulses from non-explosive and explosive scaring devices, especially if attracted to the area for feeding or reproduction (Mate and Harvey 1987; Reeves et al. 1996). Thus, pinnipeds are expected to be rather tolerant of, or habituate to, repeated underwater sounds from distant seismic sources, at least when the animals are strongly attracted to the area.

In the United Kingdom, a radio-telemetry study has demonstrated short-term changes in the behavior of harbor (=common) seals and grey seals exposed to airgun pulses (Thompson et al. 1998). In this study, harbor seals were exposed to seismic pulses from a 90 in^3 array (3 × 30 in^3 airguns), and behavioral responses differed among individuals. One harbor seal avoided the array at distances up to 2.5 km (1.3 n.mi.) from the source and only resumed foraging dives after seismic stopped. Another harbor seal exposed to the same small airgun array showed no detectable behavioral response, even when the array was within 500 m (1641 ft). All grey seals exposed to a single 10 in^3 airgun showed an avoidance reaction. Seals moved away from the source, increased swim speed and/or dive duration, and switched from foraging dives to predominantly transit dives. These effects appeared to be short-term as all grey seals either remained in, or returned at least once to, the foraging area where they had been exposed to seismic pulses. These results suggest that there are interspecific as well as individual differences in seal responses to seismic sounds.

Off California, visual observations from a seismic vessel showed that California sea lions "typically ignored the vessel and array. When [they] displayed behavior modifications, they often appeared to be reacting visually to the sight of the towed array. At times, California sea lions were attracted to the array, even when it was on. At other times, these animals would appear to be actively avoiding the vessel and array. " (Arnold 1996). In Puget Sound, sighting distances for harbor seals and California sea lions tended to be larger when airguns were operating; both species tended to orient away whether or not the airguns were firing (Calambokidis and Osmek 1998).

Monitoring work in the Alaskan Beaufort Sea during 1996-2001 provided considerable information regarding the behavior of seals exposed to seismic pulses (Harris et al. 2001; Moulton and Lawson 2002). These seismic projects usually involved arrays of 6 to 16 airguns with total volumes 560 to 1500 in^3. The combined results suggest that some seals avoid the immediate area around seismic vessels. In most survey years, ringed seal sightings tended to be farther away from the seismic vessel when the airguns were operating then when they were not (Moulton and Lawson 2002). However, these avoidance movements were relatively small, on the order of 100 m (328 ft) to (at most) a few hundreds of meters, and many seals remained within 100–200 m (328–656 ft) of the trackline as the operating airgun array passed by. Seal sighting rates at the water surface were lower during airgun array operations than during no-airgun periods in each survey year except 1997.

The operation of the airgun array had minor and variable effects on the behavior of seals visible at the surface within a few hundred meters of the array. The behavioral data indicated that some seals were more likely to swim away from the source vessel during periods of airgun operations and more likely to swim towards or parallel to the vessel during non-seismic periods. No consistent relationship was observed between exposure to airgun noise and proportions of seals engaged in other recognizable behaviors, e.g. "looked" and "dove". Such a relationship might have occurred if seals seek to reduce exposure to strong seismic pulses, given the reduced airgun noise levels close to the surface where "looking" occurs (Moulton and Lawson 2002).

In summary, visual monitoring from seismic vessels has shown only slight (if any) avoidance of airguns by pinnipeds, and only slight (if any) changes in behavior. These studies show that pinnipeds frequently do not avoid the area within a few hundred meters of an operating airgun array. However, initial telemetry work suggests that avoidance and other behavioral reactions may be stronger than evident to date from visual studies.

Sirenians

Little information is available on the responses of manatees or dugongs to industrial noise sources and no information is available on the reactions of manatees to airgun noise. What information there is on manatee reactions to disturbance suggests that sirenians were disturbed by aircraft noise from a low (20–160 m) and slow (<20 km/h) helicopter (Rathbun 1988). However, many manatees exposed to boats and tourists are becoming tame, approaching both boats and people (Curtin and Tyson 1993). In Florida, more manatees are killed by collisions with boats than by any other known causes (O'Shea et al. 1985; Ackerman et al. 1989). Although manatees can apparently hear the sound frequencies emitted by outboard engines (Gerstein et al. 1999), manatees do not appear able to localize the direction from which the boat is traveling. Manatees often attempt to avoid oncoming boats by diving, turning, or swimming away, but their reaction is usually slow and does not begin until the boat is within 50–100 m, increasing the likelihood of collisions (Hartman 1979; Weigle et al. 1993). Although habituation of manatees to vessel travel has occurred in some areas, there is evidence of reduced use of some areas with chronic boat disturbance (Provancha and Provancha 1988). Winter aggregations in favored warm-water habitats can be dispersed by human activity.

In Queensland, dugongs in shallow (<2 m) water sometimes swim rapidly in response to motorboats up to 1 km away, often heading for deeper water even if that means swimming toward the vessel (Preen 1992). Dugongs in deeper water are less responsive, often diving several seconds before the boat arrives and resurfacing several seconds after it has passed.

It is unlikely that sirenians would be encountered in waters deep enough for a large seismic vessel to operate. They prefer water shallower and closer to shore than that where major seismic vessels normally operate.

(f) Hearing Impairment and Other Physical Effects

Temporary or permanent hearing impairment is a possibility when marine mammals are exposed to very strong sounds, but there has been no specific documentation of this in the case of exposure to sounds from seismic surveys. Current NMFS policy regarding exposure of marine mammals to high-level sounds is that cetaceans and pinnipeds should not be exposed to impulsive sounds exceeding 180 and 190 dB re 1 μPa (rms), respectively (NMFS 2000). Those criteria have been used in establishing the safety (=shutdown) radii planned for numerous seismic surveys. However, those criteria were established before there was any information about the minimum received levels of sounds necessary to cause auditory impairment in marine mammals. As discussed below,

- the 180 dB criterion for cetaceans is probably quite precautionary, i.e., lower than necessary to avoid Temporary Threshold Shift (TTS) let alone permanent auditory injury, at least for delphinids.
- the minimum sound level necessary to cause permanent hearing impairment is higher, by a variable and generally unknown amount, than the level that induces barely-detectable TTS.
- the level associated with the onset of TTS is often considered to be a level below which there is no danger of permanent damage.

Several aspects of the monitoring and mitigation measures that are now often implemented during seismic survey projects are designed to detect marine mammals occurring near the airgun array, and to avoid exposing them to sound pulses that might cause hearing impairment. In addition, many cetaceans are likely to show some avoidance of the area with ongoing seismic operations (see above). In these cases, the avoidance responses of the animals themselves will reduce or avoid the possibility of hearing impairment.

Non-auditory physical effects may also occur in marine mammals exposed to strong underwater pulsed sound. Possible types of non-auditory physiological effects or injuries that might (in theory) occur include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. It is possible that some marine mammal species (i.e., beaked whales) may be especially susceptible to injury and/or stranding when exposed to strong pulsed sounds.

Temporary Threshold Shift (TTS)

TTS is the mildest form of hearing impairment that can occur during exposure to a strong sound (Kryter 1985). While experiencing TTS, the hearing threshold rises and a sound must be stronger in order to be heard. TTS can last from minutes or hours to (in cases of strong TTS) days. The magnitude of TTS depends on the level and duration of noise exposure, among other considerations (Richardson et al. 1995). For sound exposures at or somewhat above the TTS threshold, hearing sensitivity recovers rapidly after exposure to the noise ends. Only a few data on sound levels and durations necessary to elicit mild TTS have been obtained for marine mammals, and none of the published data concern TTS elicited by exposure to multiple pulses of sound.

Toothed Whales.—Ridgway et al. (1997) and Schlundt et al. (2000) exposed bottlenose dolphins and beluga whales to single 1-s pulses of underwater sound. TTS generally became evident at received levels of 192 to 201 dB re 1 µPa rms at 3, 10, 20, and 75 kHz, with no strong relationship between frequency and onset of TTS across this range of frequencies. At 75 kHz, one dolphin exhibited TTS at 182 dB, and at 0.4 kHz, no dolphin or beluga exhibited TTS after exposure to levels up to 193 dB (Schlundt et al. 2000). There was no evidence of permanent hearing loss; all hearing thresholds returned to baseline values at the end of the study.

Finneran et al. (2000) exposed bottlenose dolphins and a beluga whale to single underwater pulses designed to generate sounds with pressure waveforms similar to those produced by distant underwater explosions. Pulses were of 5.1 to 13 milliseconds (ms) in duration and the measured frequency spectra showed a lack of energy below 1 kHz. Exposure to those impulses at a peak received SPL (sound pressure level) of 221 dB re 1 µPa produced no more than a slight and temporary reduction in hearing.

A similar study was conducted by Finneran et al. (2002) using an 80 in^3 water gun, which generated impulses with higher peak pressures and total energy fluxes than used in the aforementioned study. Water gun impulses were expected to contain proportionally more energy at higher frequencies than airgun pulses (Hutchinson and Detrick 1984). "Masked TTS" (MTTS) was observed in a beluga after exposure to a single impulse with peak-to-peak pressure of 226 dB re 1 μPa, peak pressure of 160 kPa, and total energy flux of 186 dB re 1 $\mu Pa^2 \cdot s$. Thresholds returned to within 2 dB of pre-exposure value ~4 min after exposure. No MTTS was observed in a bottlenose dolphin exposed to one pulse with peak-to-peak pressure of 228 dB re 1 μPa, equivalent to peak pressure 207 kPa and total energy flux of 188 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2000, 2002). In this study, TTS was defined as occurring when there was a 6 dB or larger increase in post-exposure thresholds; the reference to masking (MTTS) refers to the fact that these measurements were obtained under conditions with substantial (but controlled) background noise. Pulse duration at the highest exposure levels, where MTTS became evident in the beluga, was typically 10–13 ms.

The data quoted above all concern exposure of small odontocetes to single pulses of duration 1 s or shorter, generally at frequencies higher than the predominant frequencies in airgun pulses. With single short pulses, the TTS threshold appears to be (to a first approximation) a function of the energy content of the pulse (Finneran et al. 2002). The degree to which this generalization holds for other types of signals is unclear (Nachtigall et al. 2003). In particular, additional data are needed in order to determine the received sound levels at which small odontocetes would start to incur TTS upon exposure to repeated, low-frequency pulses of airgun sound with variable received levels. Given the results of the aforementioned studies and a seismic pulse duration (as received at close range) of ~20 ms, the received level of a single seismic pulse might need to be on the order of 210 dB re 1 μPa rms (approx. 221–226 dB pk-pk) in order to produce brief, mild TTS. Exposure to several seismic pulses at received levels near 200–205 dB (rms) might result in slight TTS in a small odontocete, assuming the TTS threshold is (to a first approximation) a function of the total received pulse energy. Seismic pulses with received levels of 200–205 dB or more are usually restricted to a radius of no more than 100 m (328 ft) around a seismic vessel.

Baleen Whales.—There are no data, direct or indirect, on levels or properties of sound that are required to induce TTS in any baleen whale.

Pinnipeds.—TTS thresholds for pinnipeds exposed to brief pulses (either single or multiple) have not been measured. Two California sea lions did not incur TTS when exposed to single brief pulses with received levels (rms) of ~178 and 183 dB re 1 μPa and total energy fluxes of 161 and 163 dB re 1 $\mu Pa^2 \cdot s$ (Finneran et al. 2003). However, prolonged exposures show that some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes exposed for similar durations. For sounds of relatively long duration (20–22 min), Kastak et al. (1999) reported that they could induce mild TTS in California sea lions, harbor seals, and northern elephant seals by exposing them to underwater octave-band noise at frequencies in the 100–2000 Hz range. Mild TTS became evident when the received levels were 60–75 dB above the respective hearing thresholds, i.e., at received levels of about 135–150 dB. Three of the five subjects showed shifts of ~4.6–4.9 dB and all recovered to baseline hearing sensitivity within 24 hours of exposure. Schusterman et al. (2000) showed that TTS thresholds of these seals were somewhat lower when the animals were exposed to the sound for 40 min than for 20–22 min, confirming that there is a duration effect in pinnipeds. There are some indications that, for corresponding durations of sound, some pinnipeds may incur TTS at somewhat lower received levels than do small odontocetes (Kastak et al. 1999; Ketten et al. 2001; *cf*. Au et al. 2000).

Likelihood of Incurring TTS.—A marine mammal within a radius of ≤100 m (≤328 ft) around a typical array of operating airguns might be exposed to a few seismic pulses with levels of ≥205 dB, and possibly more pulses if the mammal moved with the seismic vessel.

As shown above, most cetaceans show some degree of avoidance of seismic vessels operating an airgun array. It is unlikely that these cetaceans would be exposed to airgun pulses at a sufficiently high level for a sufficiently long period to cause more than mild TTS, given the relative movement of the vessel and the marine mammal. However, TTS would be more likely in any odontocetes that bow-ride or otherwise linger near the airguns. While bow-riding, odontocetes would be at or above the surface, and thus not exposed to strong sound pulses given the pressure-release effect at the surface. However, bow-riding animals generally dive below the surface intermittently. If they did so while bow-riding near airguns, they would be exposed to strong sound pulses, possibly repeatedly. If some cetaceans did incur TTS through exposure to airgun sounds in this manner, this would very likely be a temporary and reversible phenomenon.

Some pinnipeds show avoidance reactions to airguns, but their avoidance reactions are not as strong or consistent as those of cetaceans (see above). Pinnipeds occasionally seem to be attracted to operating seismic vessels. As previously noted, there are no specific data on TTS thresholds of pinnipeds exposed to single or multiple low-frequency pulses. It is not known whether pinnipeds near operating seismic vessels, and especially those individuals that linger nearby, incur significant TTS.

NMFS (1995, 2000) concluded that cetaceans should not be exposed to pulsed underwater noise at received levels exceeding 180 dB re 1 µPa (rms). The corresponding limit for pinnipeds has been set at 190 dB. These sound levels are ***not*** considered to be the levels above which TTS might occur. Rather, they are the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements for marine mammals started to become available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As discussed above, TTS data that have subsequently become available imply that, at least for dolphins, TTS is unlikely to occur unless the dolphins are exposed to airgun pulses stronger than 180 dB re 1 µPa rms.

It has been shown that most large whales tend to avoid ships and associated seismic operations. In addition, ramping up airgun arrays, which is standard operational protocol for many seismic operators, should allow cetaceans to move away from the seismic source and to avoid being exposed to the full acoustic output of the airgun array. [Three species of baleen whales that have been exposed to pulses from single airguns showed avoidance (Malme et al. 1984–1988; Richardson et al. 1986; McCauley et al. 1998, 2000a,b). This strongly suggests that baleen whales will begin to move away during the initial stages of a ramp up, when a single airgun is fired.] Thus, whales will likely not be exposed to high levels of airgun sounds. Likewise, any whales close to the trackline could move away before the sounds from the approaching seismic vessel become sufficiently strong for there to be any potential for TTS or other hearing impairment. Therefore, there is little potential for whales to be close enough to an airgun array to experience TTS. Furthermore, in the event that a few individual cetaceans did incur TTS through exposure to airgun sounds, this is a temporary and reversible phenomenon.

Permanent Threshold Shift (PTS)

When PTS occurs, there is physical damage to the sound receptors in the ear. In some cases, there can be total or partial deafness, while in other cases, the animal has an impaired ability to hear sounds in specific frequency ranges. Physical damage to a mammal's hearing apparatus can occur if it is exposed to sound impulses that have very high peak pressures, especially if they have very short rise times (time required for sound pulse to reach peak pressure from the baseline pressure). Such damage can result in a permanent decrease in functional sensitivity of the hearing system at some or all frequencies.

There is no specific evidence that exposure to pulses of airgun sound can cause PTS in any marine mammal. However, given the possibility that mammals close to an airgun array might incur TTS, there has been speculation about the possibility that some individuals occurring very close to airguns might incur TTS (Richardson et al. 1995, p. 372*ff*).

Single or occasional occurrences of mild TTS are not indicative of permanent auditory damage in terrestrial mammals. Relationships between TTS and PTS thresholds have not been studied in marine mammals but are assumed to be similar to those in humans and other terrestrial mammals. The low-to-moderate levels of TTS that have been induced in captive odontocetes and pinnipeds during recent controlled studies of TTS have been confirmed to be temporary, with no measurable residual PTS (Kastak et al. 1999; Schlundt et al. 2000; Finneran et al. 2002; Nachtigall et al. 2003). However, very prolonged exposure to sound strong enough to elicit TTS, or shorter-term exposure to sound levels well above the TTS threshold, can cause PTS, at least in terrestrial mammals (Kryter 1985). In terrestrial mammals, the received sound level from a single non-impulsive sound exposure must be far above the TTS threshold for any risk of permanent hearing damage (Kryter 1994; Richardson et al. 1995). For impulse sounds with very rapid rise times (e.g., those associated with explosions or gunfire), a received level not greatly in excess of the TTS threshold may start to elicit PTS. Rise times for airgun pulses are rapid, but less rapid than for explosions.

Some factors that contribute to onset of PTS, at least in terrestrial mammals, are as follows:

- exposure to single very intense sound,
- repetitive exposure to intense sounds that individually cause TTS but not PTS, and
- recurrent ear infections or (in captive animals) exposure to certain drugs.

Cavanagh (2000) has reviewed the thresholds used to define TTS and PTS. Based on this review and SACLANT (1998), it is reasonable to assume that PTS might occur at a received sound level 20 dB or more above that inducing mild TTS. However, for PTS to occur at a received level only 20 dB above the TTS threshold, the animal probably would have to be exposed to a strong sound for an extended period, or to a strong sound with rather rapid rise time.

Sound impulse duration, peak amplitude, rise time, and number of pulses are the main factors thought to determine the onset and extent of PTS. Based on existing data, Ketten (1994) has noted that the criteria for differentiating the sound pressure levels that result in PTS (or TTS) are location and species-specific. PTS effects may also be influenced strongly by the health of the receiver's ear.

Given that marine mammals are unlikely to be exposed to received levels of seismic pulses that could cause TTS, it is highly unlikely that they would sustain permanent hearing impairment. If we assume that the TTS threshold for exposure to a series of seismic pulses may be on the order of 220 dB re 1 μPa (pk-pk) in odontocetes, then the PTS threshold might be as high as 240 dB re 1 μPa (pk-pk). In the units used by geophysicists, this is 10 bar-m. Such levels are found only in the immediate vicinity of the largest airguns (Richardson et al. 1995:137; Caldwell and Dragoset 2000). It is very unlikely that an odontocete would remain within a few meters of a large airgun for sufficiently long to incur PTS. The TTS (and thus PTS) thresholds of baleen whales and pinnipeds may be lower, and thus may extend to a somewhat greater distance. However, baleen whales generally avoid the immediate area around operating seismic vessels, so it is unlikely that a baleen whale could incur PTS from exposure to airgun pulses. Pinnipeds, on the other hand, often do not show strong avoidance of operating airguns.

Although it is unlikely that airgun operations during most seismic surveys would cause PTS in marine mammals, caution is warranted given the limited knowledge about noise-induced hearing damage in marine mammals, particularly baleen whales. Commonly-applied monitoring and mitigation measures, including visual monitoring, course alteration, ramp ups, and power downs or shut downs of the airguns when mammals are seen within the "safety radii", would minimize the already-low probability of exposure of marine mammals to sounds strong enough to induce PTS.

(g) Strandings and Mortality

Marine mammals close to underwater detonations of high explosive can be killed or severely injured, and the auditory organs are especially susceptible to injury (Ketten et al. 1993; Ketten 1995). Airgun pulses are less energetic and have slower rise times, and there is no proof that they can cause serious injury, death, or stranding. However, the association of mass strandings of beaked whales with naval exercises and, in a recent (2002) case, an L-DEO seismic survey, has raised the possibility that beaked whales may be especially susceptible to injury and/or behavioral reactions that can lead to stranding when exposed to strong pulsed sounds.

In March 2000, several beaked whales that had been exposed to repeated pulses from high intensity, mid-frequency military sonars stranded and died in the Providence Channels of the Bahamas Islands, and were subsequently found to have incurred cranial and ear damage (NOAA and USN 2001). Based on post-mortem analyses, it was concluded that an acoustic event caused hemorrhages in and near the auditory region of some beaked whales. These hemorrhages occurred before death. They would not necessarily have caused death or permanent hearing damage, but could have compromised hearing and navigational ability (NOAA and USN 2001). The researchers concluded that acoustic exposure caused this damage and triggered stranding, which resulted in overheating, cardiovascular collapse, and physiological shock that ultimately led to the death of the stranded beaked whales. During the event, five naval vessels used their AN/SQS-53C or -56 hull-mounted active sonars for a period of 16 h. The sonars produced narrow (<100 Hz) bandwidth signals at center frequencies of 2.6 and 3.3 kHz (-53C), and 6.8 to 8.2 kHz (-56). The respective source levels were usually 235 and 223 dB re 1 µPa, but the -53C briefly operated at an unstated but substantially higher source level. The unusual bathymetry and constricted channel where the strandings occurred were conducive to channeling sound. This, and the extended operations by multiple sonars, apparently prevented escape of the animals to the open sea. In addition to the strandings, there are reports that beaked whales were no longer present in the Providence Channel region after the event, suggesting that other beaked whales either abandoned the area or perhaps died at sea (Balcomb and Claridge 2001).

Other strandings of beaked whales associated with operation of military sonars have also been reported (e.g., Simmonds and Lopez-Jurado 1991; Frantzis 1998). In these cases, it was not determined whether there were noise-induced injuries to the ears or other organs. Another stranding of beaked whales (15 whales) happened on 24-25 September 2002 in the Canary Islands, where naval maneuvers were taking place. A recent paper concerning the Canary Islands stranding concluded that cetaceans might be subject to decompression injury in some situations (Jepson et al. 2003). If so, this might occur if they ascend unusually quickly when exposed to aversive sounds. Previously it was widely assumed that diving marine mammals are not subject to the bends or air embolism.

It is important to note that seismic pulses and mid-frequency sonar pulses are quite different. Sounds produced by the types of airgun arrays used to profile sub-sea geological structures are broadband with most of the energy below 1 kHz. Typical military mid-frequency sonars operate at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time (though the center frequency may change over time). Because seismic and sonar sounds have considerably different characteristics and duty cycles, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar pulses can, in special circumstances, lead to hearing damage and, indirectly, mortality suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity pulsed sound.

As discussed earlier, there has been a recent (Sept. 2002) stranding of two Cuvier's beaked whales in the Gulf of California (Mexico) when a seismic survey by the L-DEO/NSF vessel R/V *Maurice Ewing* was underway in the general area (Malakoff 2002). The airgun array in use during that project was the *Ewing*'s 20-airgun 8490-in^3 array. This might be a first indication that seismic surveys can have effects, at least on beaked whales, similar to the suspected effects of naval sonars. However, the evidence linking the Gulf of California strandings to the seismic surveys is inconclusive, and to this date is not based on any physical evidence (Hogarth 2002; Yoder 2002). The ship was also operating its multibeam bathymetric sonar at the same time but, as discussed elsewhere, this sonar had much less potential than the aforementioned naval sonars to affect beaked whales. Although the link between the Gulf of California strandings and the seismic (plus multibeam sonar) survey is inconclusive, this plus the various incidents involving beaked whale strandings "associated with" naval exercises suggests a need for caution in conducting seismic surveys in areas occupied by beaked whales.

(h) Non-auditory Physiological Effects

Possible types of non-auditory physiological effects or injuries that might theoretically occur in marine mammals exposed to strong underwater sound might include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage. There is no proof that any of these effects occur in marine mammals exposed to sound from airgun arrays. However, there have been no direct studies of the potential for airgun pulses to elicit any of these effects. If any such effects do occur, they would probably be limited to unusual situations when animals might be exposed at close range for unusually long periods.

Long-term exposure to anthropogenic noise may have the potential of causing physiological stress that could affect the health of individual animals or their reproductive potential, which in turn could (theoretically) cause effects at the population level (Gisiner [ed.] 1999). However, there is essentially no information about the occurrence of noise-induced stress in marine mammals. Also, it is doubtful that any single marine mammal would be exposed to strong seismic sounds for sufficiently long that significant physiological stress would develop. This is particularly so in the case of seismic surveys where the tracklines are long and/or not closely spaced, as is the case for most two-dimensional seismic surveys.

Gas-filled structures in marine animals have an inherent fundamental resonance frequency. If stimulated at this frequency, the ensuing resonance could cause damage to the animal. There may also be a possibility that high sound levels could cause bubble formation in the blood of diving mammals that in turn could cause an air embolism, tissue separation, and high, localized pressure in nervous tissue (Gisiner [ed.] 1999; Houser et al. 2001). A recent workshop (Gentry [ed.] 2002) was held to discuss whether the stranding of beaked whales in the Bahamas in 2000 might have been related to air cavity resonance or bubble formation in tissues caused by exposure to noise from naval sonar. A panel of experts concluded that resonance in air-filled structures was not likely to have caused this stranding. Among other reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry [ed.] 2002). Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area. The only available information on acoustically-mediated bubble growth in marine mammals is modeling assuming prolonged exposure to sound.

As noted in the preceding subsection, a recent paper (Jepson et al. 2003) has suggested that cetaceans can at times be subject to decompression sickness. If so, this could be another mechanism by which exposure to strong sounds could, indirectly, result in non-auditory injuries and perhaps death.

In summary, very little is known about the potential for seismic survey sounds to cause either auditory impairment or other non-auditory physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to short distances. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

Literature Cited

Literature mentioned in this Appendix is listed in the overall Literature Cited section earlier in this document.